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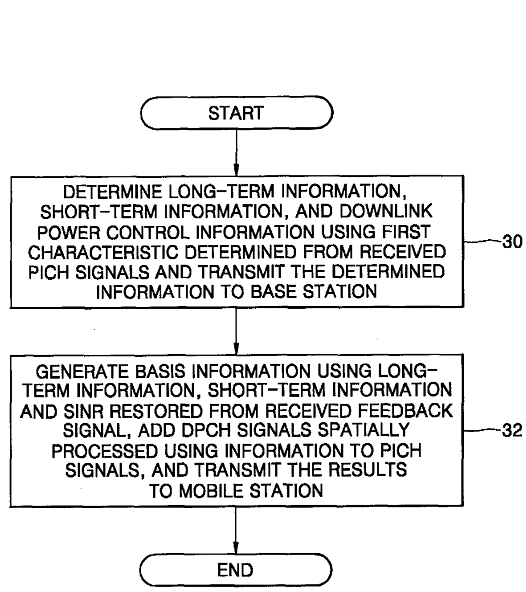
(54) **Mobile communication apparatus with multiple transmission and reception antennas and mobile communication method therefor**

(57) A mobile communication apparatus with multiple transmission and reception antennas and a mobile communication method therefor are provided. In the mobile communication apparatus including a base station and a mobile station, the base station with at least one transmission antenna restores long-term information, short-term information, a signal to interference and noise ratio (SINR) from a feedback signal received from the mobile station, spatially processes dedicated physical channel (DPCH) signals using basis information generated from the restored long-term information, short-term information and SINR and transmits the results of adding pilot channel (PICH) signals to the spatially processed results to the mobile station. The mobile station with at least one reception antenna determines a first characteristic corresponding to the channel downlink characteristic for each of the transmission and reception antennas, from the PICH signals transmitted from the base station, determines the long-term information, the short-term information, and downlink power control information including the SINR, which reflect the first characteristic, converts the determined long-term information, short-term information, and downlink power control information into the feedback signal, and transmits the feedback signal to the base station. The long-term information includes effective long-term eigenvectors and effective long-term eigenvalues, the short-term information includes effective short-term eigenvectors, and the downlink power control information indicates whether to increase or decrease downlink transmission power. Therefore, with the great advantage of closed communications systems the effects of interference, noise, and fading can be minimized, whereas throughput can be maximized.

FIG. 2



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Description

[0001] The present invention relates to mobile communications, and more particularly, to a mobile communication apparatus with multiple transmission and reception antennas and a mobile communication method therefor, which can minimize the effects of fading, interference, and noise.

[0002] Next-generation mobile communication systems require high-speed data transmission, faster than the mobile communication systems for personal communication service. As a wireless communication standard, Europe and Japan have adopted the wideband code division multiple access (W-CDMA) scheme, and North America has adopted the CDMA-2000 scheme.

[0003] A mobile communication system is commonly constructed of a base station and a plurality of mobile stations communicating with each other via the base station. High-speed data transmission in a mobile communication system can be achieved by minimizing user co-interference and signal loss, such as fading, affected by channel characteristics. Diversity techniques have been applied to prevent unstable communications due to fading. One such technique, a space diversity technique, uses multiple antennas.

[0004] Use of multiple antennas is considered to be necessary for future mobile communication systems as it can minimize user co-interference. A transmission multiple antenna system used to increase the capacity of a transmitter, which employs a diversity technique using multiple antennas to counteract signal fading, requires a wide bandwidth for transmission due to a feature of next generation mobile communications.

[0005] For high-speed data transmission, it is essential to solve the problem of signal fading, which is the most significant channel characteristic affecting the performance of common mobile communication systems. This is because fading may reduce the amplitude of a received signal to tens of dB or even a few dB. Many kinds of diversity techniques are applied to overcome fading. A common CDMA technique utilizes a Rake receiver, which receives multiple path signals using the delay spread of a channel and corresponds to a reception diversity technique. However, this reception diversity technique is not effective when the delay spread is small.

[0006] Doppler spread channels require a time diversity technique using interleaving and coding techniques. However, the time diversity technique cannot be applied to a low-speed Doppler channel. An interior channel with a small delay spread and a pedestrian channel, which is a typical example of a low-speed Doppler channel, require a space diversity technique to counteract fading. The space diversity technique uses two or more antennas to overcome signal attenuation due to fading during transmission by switching antennas. Space diversity is classified into reception antenna diversity requiring reception antennas and transmission antenna diversity requiring transmission antennas. It is impractical in terms of cost and space utilization to adopt reception antenna diversity at individual mobile stations; instead, transmission antenna diversity is adopted at the base station.

[0007] Transmission antenna diversity is categorized into closed-loop transmission diversity where mobile stations feed downlink channel information back to the base station and open-loop transmission diversity where no feedback occurs from mobile stations to the base station. According to a transmission diversity approach, a mobile station determines the phase and magnitude on each channel to find optimal weight values. For this determination of the phase and amplitude on the channel, the base station transmits a pilot signal through each antenna to the mobile station. Then, the mobile station determines the magnitude and phase on the channel from each pilot signal and finds optimal weight values based on the magnitude and phase on the channel.

[0008] In transmission antenna diversity, diversity effects and signal-to-noise ratio improve as the number of antennas increases. However, the improvement of diversity efficiency decreases as the number of antennas (or signal transmission paths) used at the base station, i.e., the degree of diversity, increases. Therefore, continuing to increase the number of antennas beyond a certain point merely to achieve an extremely high diversity effect would be costly and impractical. However, increasing the number of antennas used in the base station to minimize the power of interference signals and to maximize the internal signal-to-noise ratio is an effective and quite practical technique.

[0009] A transmission adaptive antenna array system that provides diversity effects as well as beamforming effects to protect an internal signal from interference and noise is called a "downlink beamforming system." Particularly, a system that utilizes feedback information as in transmission diversity is called a "closed loop downlink beamforming system." Closed downlink beamforming systems that use information fed back from mobile stations to the base station require a sufficiently wide feedback channel bandwidth. If the feedback channel bandwidth is not sufficiently wide, communication performance degrades due to poor adaptability to channel information variations.

[0010] The European IMT-2000 standardization association has adopted transmission antenna array (TxAA) modes 1 and 2, which are closed loop transmission diversity schemes for two antennas, in the 3 GPP (Generation Partnership Project) R (Release) 99 version. TxAA mode 1, suggested by Nokia, feeds back only a phase variation between two antennas, whereas TxAA mode 2, suggested by Motorola, feeds back the gains as well as phases of two antennas. TxAA modes 1 and 2 are disclosed in the specification for the UMTS (Universal Mobile Telecommunications System) by the 3 GPP.

[0011] TxAA mode 1 or 2 for closed loop transmission diversity uses an adaptive antenna array and applies different complex number weights to each antenna of the adaptive transmission antenna array. The weights applied to the adaptive antenna array are associated with transmission channels and thus are expressed as, for example, $\boldsymbol{w}=\boldsymbol{h}^*$. Here, $\boldsymbol{w}$ is a transmission antenna array weight vector, and $\boldsymbol{h}$ is a transmission array channel vector. Hereinafter, bold symbols indicate vectors and non-bold symbols indicate scalars.

[0012] In general, in a mobile communications system using a frequency division duplex (FDD) technique, transmission and reception channels have different characteristics, so there is need to feed back transmission channel information by the base station to identify the characteristic of a transmission channel $\boldsymbol{h}$. According to TxAA mode 1 or 2, a mobile station calculates weight information $\boldsymbol{w}$ to be obtained from the channel information $\boldsymbol{h}$ and feeds the calculated weigh information back to the base station.

[0013] TxAA mode 1 quantizes only the phase component of the weight information $\boldsymbol{w}$, $\theta_2 - \theta_1$, into two bits and feeds back the result of the quantization. The weight information $\boldsymbol{w}$ is expressed as $\boldsymbol{w} = [|w_1|\exp(j\theta_1), |w_2|\exp(j\theta_2)]$, where w_1 and w_2 are scalars. Here, the phase accuracy is $\pi/2$, and the maximum quantization error is $\pi/4$. A refined mode of updating only one of two bits at every time point is applied to increase feedback efficiency. As an example, possible combinations of two bits include {b(2k), b(2k-1)} and {b(2k), b(2k+1)}, where b indicates a bit fed back during every consecutive time slot.

[0014] TxAA mode 2 feeds back both the constituents, the phase and gain, of the weight information. The phase of the weight information is fed back as 3 bits, and the gain of the weight information is fed back as 1 bit. Therefore, the phase accuracy is $\pi/4$, and the maximum quantization error is $\pi/8$. A progressive refined mode of updating only one of four bits at every time point is applied to increase feedback efficiency. This progressive refine mode provides no prescription, unlike the refine mode having the prescription that each bit should be an orthogonal basis value.

[0015] The above-described TxAA modes 1 and 2 have the following problems when the number of antennas and space-time channel characteristics vary.

[0016] First, when the number of antennas increases, the quantity of weights for each antenna that should be fed back also increases, and thus communication performance may degrade depending on the migration speed of a mobile station. With increasing migration speed of a mobile station, space-time channel variations become serious on a common fading channel. In this case, the feedback speed of channel information should be increased. For this reason, if the feedback speed of channel information is limited, communication performance may degrade due to an increase in the amount of feedback information with increasing number of antennas.

[0017] Second, when antennas are not spaced sufficiently far apart, the correlation between channels for each antenna increases. This increased channel-to-channel correlation reduces the quantity of information carried in a channel matrix. Use of an effective feedback scheme can prevent communication performance degradation occurring with a mobile station migrating at a rapid speed, even with the increasing number of antennas. However, because TxAA modes 1 and 2 are defined under the assumption that space-time channels for two antennas are independent, efficiency is not ensured when the number of antennas and space-time channel characteristics vary. In addition, TxAA modes 1 and 2 have not been applied for circumferences using more than two antennas.

[0018] According to an aspect of the present invention, there is provided a mobile communication apparatus with multiple transmission and reception antennas, the apparatus comprising a base station and a mobile station, wherein:

the base station with at least one transmission antenna is arranged to restore long-term information, short-term information and a signal to interference and noise ratio (SINR) from a feedback signal received from the mobile station, spatially processes dedicated physical channel (DPCH) signals using basis information generated from the restored long-term information, short-term information, and SINR and transmits the results of adding pilot channel (PICH) signals to the spatially processed results to the mobile station;

the mobile station with at least one reception antenna is arranged to determine a first characteristic corresponding to the channel downlink characteristic for each of the transmission and reception antennas, from the PICH signals transmitted from the base station, determines the long-term information, the short-term information, and downlink power control information including the SINR, which reflect the first characteristic, converts the determined long-term information, short-term information, and downlink power control information into the feedback signal, and transmits the feedback signal to the base station; and

the long-term information includes effective long-term eigenvectors and effective long-term eigenvalues, the short-term information includes effective short-term eigenvectors, and the downlink power control information indicates whether to increase or decrease downlink transmission power.

[0019] The present invention thus provides a mobile communication apparatus with multiple transmission and reception antennas, in which minimum amounts of long-term information and short-term information reflecting the downlink characteristic of spatial channels for each of the transmission and reception antennas of the base station and mobile stations, which have multiple transmission and reception antennas, respectively, are fed back from a mobile station to a base station to minimize the effects of interference, noise and fading and to maximize data transmission throughput.

[0020] According to another aspect of the present invention, there is provided a mobile station comprising:

at least one reception antenna;
a channel characteristic determination unit which determines a first characteristic from pilot channel (PICH) signals received via the at least one reception antenna, determines a second characteristic from the first characteristic, and generates a signal to interference and noise ratio (SINR) from the generated second characteristic;
a long-term information determination unit which determines long term information including effective long-term eigenvectors and effective long-term eigenvalues using the second characteristic input from the channel characteristic determination unit;
a short-term information determination unit which determines short term information including effective short-term eigenvectors using the second characteristic input from the channel characteristic determination unit and the long-term information;
a high-rate feedback unit which encodes the effective short-term eigenvectors input from the short-term information determination unit as bits and outputs the result of the bit encoding at first predetermined time intervals as high-rate feedback information;
a low-rate feedback unit which encodes the long-term information input from the long-term information determination unit as bits and outputs the result of the bit encoding at second predetermined time intervals as low-rate feedback information;
a downlink power control unit which generates downlink power control information from the SINR generated by the channel characteristic determination unit and outputs the generated downlink power control information; and
a signal conversion unit which multiplexes the high-rate feedback information, the low-rate feedback information, and the downlink power control information and outputs the multiplexed result to the at least one reception antenna as a feedback signal,

wherein the at least one reception antenna transmits the feekback signal to a base station having at least one transmission antenna, the second characteristic corresponds to an instantaneous correlation of the channel downlink characteristic for each of the transmission and reception antennas, and the first predetermined time interval is shorter than the second predetermined time interval.

[0021] According to another aspect of the present invention, there is provided a base station comprising:

at least one transmission antenna;
an information restoration unit which restores long-term information, effective short-term eigenvectors, and the signal to interference and noise ratio (SINR) from a feedback signal received via the at least one transmission antenna and outputs the restored long-term information, effective short-term eigenvectors and SINR;
a basis information generation unit which generates basis vectors and gain values as basis information from the restored long-term information, effective short-term eigenvectors and SINR;
a gain adjustment unit which adjusts the amplitudes of dedicated physical channel (DPCH) signals according to the gain values and outputs the adjusted results;
a basis vector application unit which applies the basis vectors to the adjusted results input from the gain adjustment unit and outputs the results as spatially processed results; and
an addition unit which adds pilot channel (PICH) signals to the spatially adjusted results and outputs the added results,

wherein the at least one transmission antennas transmits the added results to a mobile station.

[0022] According to another aspect of the present invention, there is provided a mobile communication method performed between a base station with at least one transmission antenna and a mobile station with at least one reception antenna, the method comprising a step of (a) restoring long-term information, short-term information and an SINR determined in the mobile station reflecting a first characteristic corresponding to a channel downlink characteristic for each of the transmission and reception antennas, from a feedback signal received from the mobile station, spatially processing DPCH signals using basis information generated from the restored long-term information, short-term information and SINR, adding PICH signals to the spatially processed results, and transmitting the added results to the mobile station, wherein the long-term information includes effective long-term eigenvectors and effective long-term eigenvalues, and the short-term information includes effective short-term eigenvectors.

[0023] The present invention thus provides a mobile communication method performed in the above mobile communication apparatus with the multiple transmission and reception antennas.

[0024] Exemplary embodiments of the present invention will now be described in detail with reference to the attached drawings in which:

FIG. 1 shows a mobile communication apparatus according to the present invention;
FIG. 2 shows a flowchart illustrating a mobile communication method according to the present invention performed in the mobile communication apparatus of FIG. 1;
FIG. 3 shows a flowchart illustrating an embodiment of Step 30 of FIG. 2 according to the present invention;
FIG. 4 shows a block diagram of an embodiment according to the present invention of a first mobile station, second mobile station, or X^{th} mobile station shown in FIG. 1;
FIG. 5 shows a flowchart illustrating a preferred embodiment for Step 42 of FIG. 3 according to the present invention;
FIG. 6 shows a block diagram of an embodiment of a long-term information determination unit of FIG. 4 according to the present invention;
FIG. 7 shows a flowchart illustrating an embodiment of Step 92 of FIG. 5 according to the present invention;
FIG. 8 shows a flowchart illustrating an embodiment of Step 44 of FIG. 3 according to the present invention;
FIG. 9 shows a block diagram of a short-term information determination unit of FIG. 4 according to the present invention;
FIG. 10 shows a flowchart illustrating an embodiment of Step 132 of FIG. 8 according to the present invention;
FIG. 11 shows a flowchart illustrating an embodiment of Step 50 of FIG. 3 according to the present invention;
FIG. 12 shows a block diagram of a downlink power control unit of FIG. 4 according to the present invention;
FIG. 13 shows a flowchart illustrating an embodiment of Step 32 of FIG. 2 according to the present invention;
FIG. 14 shows a block diagram of an embodiment of a base station of FIG. 1 according to the present invention;
FIG. 15 shows a flowchart illustrating an embodiment of Step 172 of FIG. 13 according to the present invention;
FIG. 16 shows a block diagram of an embodiment of a basis information generation unit of FIG. 14 according to the present invention;
FIG. 17 shows an example of a table used to determine effective short-term eigenvalues in the present invention;
FIG. 18 shows a flowchart illustrating an embodiment of Step 208 of FIG. 15 according to the present invention;
FIG. 19 shows a block diagram of a preferred embodiment of a third eigenvalue decomposition and calculation portion of FIG. 16, which performs the embodiment of FIG. 18, according to the present invention;
FIG. 20 shows a flowchart illustrating an embodiment of Step 174 of FIG. 13 according to the present invention;
FIG. 21 shows a flowchart illustrating an embodiment of Step 260 of FIG. 20 according to the present invention;
FIG. 22 shows a block diagram of a preferred embodiment of a gain adjustment unit of FIG. 14 according to the present invention; and
FIG. 23 shows a block diagram of an embodiment of a basis vector application unit of FIG. 14 according to the present invention.

[0025] The structure and operation of a mobile communication apparatus with multiple transmission and reception antennas, and a mobile communication method performed in the mobile communication apparatus of the present invention will be described with reference to the appended drawings.
[0026] Referring to FIG. 1, which is a schematic view of a mobile communication apparatus according to the present invention, the mobile communication apparatus includes a base station 10, and a first mobile station 20, a second mobile station 22, ..., and an X^{th} mobile station 24.
[0027] FIG. 2 shows a flowchart illustrating a mobile communication method according to the present invention performed in the mobile communication apparatus shown in FIG. 1. The mobile communication method illustrated in FIG. 2 involves obtaining a feedback signal (Step 30), and adding dedicated physical channel (DPCH) signals spatially processed using long-term information, short-term information, and a signal to interference and noise ratio (SINR) restored from the feedback signal to pilot channel (PICH) signals and transmitting the added results (Step 32).
[0028] Each of the first through X^{th} mobile stations 20 through 24 illustrated in FIG. 1 perform the same function. The base station 10 includes at least one transmission antenna, and each of the first through X^{th} mobile stations 20 through 24 includes at least one reception antenna and may be implemented, for example, with a terminal.
[0029] The base station 10 of FIG. 1 restores the long-term information, the short-term information, and the SINR from the feedback signal received from the first, second, ..., or X^{th} mobile stations 20, 22, ..., or 24, spatially processes the DPCH signals using basis information generated from the restored long-term information, short-term information and SINR, adds the spatially processed DPCH signals to the PICH signals, and transmits the added results to the first, second, ..., or X^{th} mobile stations 20, 22, ... or 24 (Step 32). Here, the PICH signals, which are expressed as $P_i(k)$, where $1 \leq i \leq B$, and B is an integer greater than or equal to 1, indicating the number of transmission antennas, may be common pilot channel (CPICH) signals, dedicated CPICH (DCPICH) signals, secondary CPICH (SCPICH) signals, etc.
[0030] When the base station 10 according to the present invention is supported to be able to operate as described above, the first, second, ..., and X^{th} mobile stations 20, 22, ..., and 24 each of which has at least one reception antenna can be implemented with any means as long as the first, second, ..., and X^{th} mobile stations 20, 22, ..., and 24 can determine long-term information, short-term information, and downlink power control information, including a SINR, which reflect the channel downlink characteristic (hereinafter, "first characteristic **H**", where **H** is a matrix) for each

transmission and reception antenna. Hereinafter, bold symbols indicate vectors and non-bold symbols indicate scalars. The channel downlink characteristic **H** for each transmission and reception antenna means the phase and amplitude, or gain of a signal transmitted from the base station 10 through a channel to the mobile station 20, 22, ..., or 24. Here, the matrix of the first characteristic **H** consists of channels for transmission antennas of the base station 10 in columns and channels for reception antennas of the first, second, ..., or X^{th} mobile stations 20, 22, ..., 24 in rows. The column components of the matrix of the first characteristic **H** are obtained in the transmission antenna space, and the row components thereof are obtained in the reception antenna space.

[0031] As an example, the first, second, ..., or X^{th} mobile station 20, 22, ... or 24 determines the first characteristic **H** from the PICH signals transmitted from the base station 10, determines long-term information, short-term information, and downlink power control information, which reflect the correlation of the characteristics between channels for each transmission and reception antenna, from the first characteristic **H** , converts the determined long-term information, short-term information, and downlink power control information into a feedback signal, and transmits the feedback signal to the base station 10 (Step 30). The long-term information includes effective long-term eigenvectors and effective long-term eigenvalues, the short-term information includes effective short-term eigenvectors, and the downlink power control information includes information as to whether to increases or decreases downlink transmission power.

[0032] For the convenience of understanding the present invention, embodiments of the first, second, ..., or X^{th} mobile station 20, 22, ..., 24 and Step 30 according to the present invention will be described first with reference to the appended drawings, followed by descriptions on embodiments of the base station 10 and Step 32 according to the present invention.

[0033] FIG. 3 shows a flowchart illustrating an embodiment 30A of Step 30 shown in FIG. 2 according to the present invention. This embodiment involves determining the first characteristic **H** and obtaining a SINR (Step 40), determining the long-term information and short-term information of the channel (Steps 42 and 44), obtaining high-rate feedback information, low-rate feedback information, and downlink power control information (Steps 46 through 50), and converting the determined high-rate feedback information, low-rate feedback information, and downlink power control information into the feedback signal (Step 52).

[0034] FIG. 4 shows a block diagram of an embodiment according to the present invention of the first mobile station 20, the second mobile station 22, ..., or the X^{th} mobile station 24 shown in FIG. 1. The mobile station shown in FIG. 4 includes an antenna array 60, a channel characteristic determination unit 70, a long-term information determination unit 72, a short-term information determination unit 74, a high-rate feedback unit 76, a low-rate feedback unit 78, a signal restoration unit 80, a signal conversion unit 82, and a downlink power control unit 84.

[0035] The antenna array 60 of FIG. 4 includes *M* reception antennas 62, 64, ..., 66, where *M* is an integer greater than or equal to 1, and receives the spatially processed DPCH signals and PICH signals transmitted from the base station 10. The channel characteristic determination unit 70 determines the first characteristic *H* from the PICH signals transmitted from the base station 10 and received through the antenna array 60, determines an instantaneous correlation of the channel downlink characteristic (hereinafter, "second characteristic **R** ") for each transmission and reception antenna, from the first characteristic **H** using equation 1 below, outputs the determined second characteristic **R** to the long-term information determination unit 72 and the short-term information determination unit 74, obtains an SINR for downlink power control from the determined second characteristic **R** using equation 2 below, and outputs the obtained SINR to the downlink power control unit 84 (Step 40). The second characteristic **R** is expressed as $B \times B$ matrix.

$$R = H^{H} \cdot H \quad (1)$$

$$SINR = \Sigma\, diag(R) \quad (2)$$

[0036] After Step 40, the long-term information determination unit 72 determines effective long-term eigenvectors $\mathbf{Q}_{LT}$ and effective long-term eigenvalues Λ_{LT} , which constitute the long-term information, from the second characteristic **R** determined by the channel characteristic determination unit 70 and outputs the determined effective long-term eigenvectors $\mathbf{Q}_{LT}$ and effective long-term eigenvalues Λ_{LT} to the short-term information determination unit 74 and the low-rate feedback unit 78, respectively (Step 42). Here, long-term eigenvalues have a one-to-one mapping relation with long-term eigenvectors. Long-term eigenvectors which are mapped one-to-one with the effective long-term eigenvalues Λ_{LT} are referred to as the effective long-term eigenvectors $\mathbf{Q}_{LT}$. The effective long-term eigenvectors $\mathbf{Q}_{LT}$ are in a $B \times N_B$ matrix, and the effective long-term eigenvalues Λ_{LT} are in a $N_B \times N_B$ matrix.

[0037] Hereinafter, embodiments of Step 42 of FIG. 3 and the long-term information determination unit 72 of FIG. 4 according to the present invention will be described with reference to the appended drawings.

[0038] FIG. 5 shows a flowchart illustrating a preferred embodiment 42A of Step 42 illustrated in FIG. 3 according to the present invention. This embodiment involves obtaining a long-term correlation of the channel downlink characteristic for each transmission and reception antenna by accumulating the second characteristic **R** (Step 90) and determining the long-term information from the obtained long-term correlation of the channel downlink characteristic (Step 92).

[0039] FIG. 6 shows a block diagram of an embodiment 72A of the long-term information determination unit 72 of FIG. 4 according to the present invention. The embodiment 72A includes an accumulation portion 100 and a first eigenvalue decomposition and calculation portion 110.

[0040] After Step 40 of FIG. 3, the accumulation portion 100 of FIG. 6 accumulates the second characteristic **R** input from the channel characteristic determination unit 70 and outputs the accumulated result $\mathbf{R}_{LT}(k)$ to the first eigenvalue decomposition and calculation portion 110 as the long-term correlation of the channel downlink characteristic (hereinafter, "third characteristic $\mathbf{R}_{LT}$ ") for each transmission and reception antenna (Step 90). The third characteristic $\mathbf{R}_{LT}$, i.e., the accumulated result $\mathbf{R}_{LT}(k)$, is expressed as $B \times B$ matrix, as in equation 3 below:

$$\mathrm{R}_{LT} = \Sigma \mathrm{H}^{\mathrm{H}} \cdot \mathrm{H} = \Sigma\, \mathrm{R}$$

$$\mathrm{R}_{LT}(k) = \rho\, \mathrm{R}_{LT}(k\text{-}1) + \mathrm{R}(k) \qquad (3)$$

where ρ is a forgetting factor, and k indicates a discrete time.

[0041] After Step 90, the first eigenvalue decomposition and calculation portion 110 generates the effective long-term eigenvectors $\mathbf{Q}_{LT}$ and effective long-term eigenvalues Λ_{LT}, which correspond to the long-term information, using the third characteristic $\mathbf{R}_{LT}$ input from the accumulation portion 100 by an eigenvalue decomposition (EVD) method and outputs the generated effective long-term eigenvectors $\mathbf{Q}_{LT}$ and effective long-term eigenvalues Λ_{LT} to the short-term information determination unit 74 and the low-rate feedback unit 78 (Step 92). The EVD technique applied in this embodiment is disclosed in "Matrix Computation", *G. Golub* and C. *Van. Loan,* Johns Hopkins University Press, London, 1996.

[0042] Hereinafter, embodiments of Step 92 of FIG. 5 and the first eigenvalue decomposition and calculation portion 110 of FIG. 6 of the present invention will be described.

[0043] FIG. 7 shows a flowchart illustrating an embodiment 92A of Step 92 of FIG. 5 according to the present invention. The embodiment 92A involves selecting the effective long-term eigenvectors $\mathbf{Q}_{LT}$ and effective long-term eigenvalues Λ_{LT} among long-term eigenvectors and long-term eigenvalues as the long-term information (Steps 120 through 124).

[0044] For performing the embodiment 92A of FIG. 7, the first eigenvalue decomposition and calculation portion 110 may be implemented with a first eigenvalue decomposer 112, a vector counter 114, and a first selector 116, as shown in FIG. 6.

[0045] After Step 90 of FIG. 5, the first eigenvalue decomposer 112 generates $B \times B$ long-term eigenvectors $\mathbf{q}_{LT1} \sim \mathbf{q}_{LTB}$ and $B \times B$ long-term eigenvalues $\lambda_{LT1} \sim \lambda_{LTB}$ using the third characteristic $\mathbf{R}_{LT}$ input from the accumulation portion 100 by the above-described EVD method, outputs the generated $B \times B$ long-term eigenvalues $\lambda_{LT1} \sim \lambda_{LTB}$ to the vector counter 114 and the first selector 116, and outputs the generated $B \times B$ long-term eigenvectors $\mathbf{q}_{LT1} \sim \mathbf{q}_{LTB}$ to the first selector 116 (Step 120).

[0046] After Step 120, the vector counter 114 counts the number of long-term eigenvalues $\lambda_{LT1} \sim \lambda_{LTB}$, which is greater than a first predetermined threshold value, determines the counted result as the number of effective long-term eigenvectors, N_B, where $1 \leq N_B \leq B$, and outputs the determined number of effective long-term eigenvectors, N_B, to the first selector 116 (Step 122). To this end, the vector counter 114 may be implemented with a counter (not shown). The first predetermined threshold value is a non-zero value approximating to zero and means a noise level in the third characteristic $\mathbf{R}_{LT}$.

[0047] After Step 122, the first selector 116 selects B long-term eigenvectors from among the $B \times B$ long-term eigenvectors $\mathbf{q}_{LT1} \sim \mathbf{q}_{LTB}$ input from the first eigenvalue decomposer 112 and outputs N_B column vectors which consist of the selected B long-term eigenvectors as the effective long-term eigenvectors $\mathbf{Q}_{LT}$ (Step 124). Also, the first selector 116 selects long-term eigenvalues in a quantity equal to the number of effective long-term eigenvectors, N_B, from which noises have been removed, among the $B \times B$ long-term eigenvalues $\lambda_{LT1} \sim \lambda_{LTB}$ input from the first eigenvalue decomposer 112 and outputs a diagonal matrix which consists of the selected long-term eigenvalues as the effective long-term eigenvalues Λ_{LT} (Step 124).

[0048] After Step 42 of FIG. 3, the short-term information determination unit 74 determines effective short-term eigenvectors $\mathbf{Q}_{ST}$, which correspond to the short-term information, using the second characteristic R input from the channel characteristic determination unit 70 and the long-term information including the effective long-term eigenvectors $\mathbf{Q}_{LT}$ and the effective long-term eigenvalues Λ_{LT} input from the long-term information determination unit 72, and outputs the determined effective short-term eigenvectors $\mathbf{Q}_{ST}$ to the high-rate feedback unit 76 (Step 44). The effective short-term eigenvectors $\mathbf{Q}_{ST}$ are in a $N_B \times (N_B\text{-}1)$ matrix.

[0049] Hereinafter, embodiments of Step 44 of FIG. 3 and the short-term information determination unit 74 of FIG. 4 according to the present invention will be described with reference to the appended drawings.

[0050] FIG. 8 shows a flowchart illustrating an embodiment 44A of Step 44 of FIG. 3 according to the present invention. The embodiment 44A involves obtaining a short-term correlation of the channel downlink characteristic for each transmission and reception antenna (Step 130) and obtaining the short-term information from the obtained short-term correlation of the channel downlink characteristic (Step 132).

[0051] FIG. 9 shows a block diagram of an embodiment 74A of the short-term information determination unit 74 of FIG. 4 according to the present invention. The embodiment 74A includes a short-term correlation determination portion 140 and a second eigenvalue decomposition and calculation portion 142.

[0052] After Step 42 of FIG. 3, the short-term correlation determination portion 140 determines a short-term correlation (hereinafter, "fourth characteristic $\mathbf{R}_{ST}$") of the channel downlink characteristic for each transmission and reception antenna from the second characteristic $\mathbf{R}$ input from the channel characteristic determination unit 70 and the long-term information including the effective long-term eigenvectors $\mathbf{Q}_{LT}$ and the effective long-term eigenvalues Λ_{LT} input from the long-term information determination unit 72, using equation 4 below, and outputs the determined fourth characteristic $\mathbf{R}_{ST}$ to the second eigenvalue decomposition and calculation portion 142 (Step 130). The fourth characteristic $\mathbf{R}_{ST}$ is expressed as a $N_B \times N_B$ matrix.

$$R_{ST} = \Lambda_{LT}^{-\frac{1}{2}} Q_{LT}^{H} R\, Q_{LT}\, \Lambda_{LT}^{-\frac{1}{2}} \qquad (4)$$

[0053] After Step 130, the second eigenvalue decomposition and calculation portion 142 determines the effective short-term eigenvectors $\mathbf{Q}_{ST}$ from the fourth characteristic $\mathbf{R}_{ST}$ input from the short-term correlation determination portion 140 by the above-described EVD method and outputs the determined effective short-term eigenvectors $\mathbf{Q}_{ST}$ to the high-rate feedback unit 76 as the short-term information (Step 132).

[0054] Hereinafter, embodiments of Step 132 of FIG. 8 and the second eigenvalue decomposition and calculation portion 142 of FIG. 9 will be described.

[0055] FIG. 10 shows a flowchart illustrating an embodiment 132A of Step 132 of FIG. 8 according to the present invention. The embodiment 132A involves selecting effective short-term eigenvectors $\mathbf{Q}_{ST}$ among short-term eigenvectors as the short-term information (Steps 150 through 152).

[0056] To implement the embodiment 132A of FIG. 10, the second eigenvalue decomposition and calculation portion 142 may be implemented with a second eigenvalue decomposer 144 and a second selector 148, as shown in FIG. 9.

[0057] After Step 130 of FIG. 8, the second eigenvalue decomposer 144 generates N_B short-term eigenvectors $\mathbf{Q}_{ST0}$, expressed as equation 5 below, using the fourth characteristic $\mathbf{R}_{ST}$ input from the short-term correlation determination portion 140 by the above-described EVD method and outputs the generated N_B short-term eigenvectors $\mathbf{Q}_{ST0}$ to the second selector 146 (Step 150).

$$Q_{ST0} \equiv [q_{ST0,1}\; q_{ST0,2} \cdots q_{ST0,\,N_B}] \qquad (5)$$

[0058] After Step 150, the second selector 148 selects N_Bx(N_B-1) short-term eigenvectors from among the N_B short-term eigenvectors $\mathbf{Q}_{ST0}$ input from the second eigenvalue decomposer 144 and outputs column vectors which consists of the selected short-term eigenvectors, expressed as equation 6 below, as the effective short-term eigenvectors $\mathbf{Q}_{ST}$ (Step 152).

$$Q_{ST} \equiv [q_{ST0,1}\; q_{ST0,2} \cdots q_{ST0,(N_B\text{-}1)}] \qquad (6)$$

[0059] After Step 44 of FIG. 3, the first mobile station 20, the second mobile station 22, ..., or the X^{th} mobile station 24 converts the short-term information including the effective short-term eigenvectors $\mathbf{Q}_{ST}$, the long-term information including the effective long-term eigenvectors $\mathbf{Q}_{LT}$ and the effective long-term eigenvalues Λ_{LT}, the downlink power control information into a feedback signal which is suitable to be fed back to the base station 10 and transmits the converted feedback signal via the antenna array 60 to the base station 10 (Steps 46 through 52).

[0060] To perform Steps 46 through 52, the high-rate feedback unit 76, the low-rate feedback unit 78, the signal conversion unit 82, and the downlink power control unit 84 are involved. After Step 44, the high-rate feedback unit 76 encodes the effective short-term eigenvectors $\mathbf{Q}_{ST}$ input from the short-information determination unit 74 as bits and outputs the result of the bit encoding to the signal conversion unit 82 as high-rate feedback information at first predetermined time intervals (Step 46). After Step 46, the low-rate feedback unit 78 encodes the long-term information, including the effective long-term eigenvectors $\mathbf{Q}_{LT}$ and the effective long-term eigenvalues Λ_{LT}, input from the long-term information determination unit 72 as bits and outputs the result of the bit encoding to the signal conversion unit 82 as low-rate feedback information at second predetermined time intervals (Step 48). Here, the first predetermined time interval is shorter than the second predetermined time interval. For example, the second predetermined time interval may be 10 times longer than the first predetermined time interval. In this case, one bit of the long-term information is output from the low-rate feedback unit 78 to the signal conversion unit 82 while 10 bits of the short-term information is output from the high-rate feedback unit 76 to the signal conversion unit 82. Accordingly, the short information can be transmitted to the signal conversion unit 82 faster than the long-term information.

[0061] After Step 48, the downlink power control unit 84 generates downlink power control information using the SINR input from the channel characteristic determination unit 70 and outputs the generated downlink power control information to the signal conversion unit 82 (Step 50). A downlink power control method is disclosed in "CDMA Systems Engineering Handbook", *J.S. Lee* and *L.E. Miller*, Artech House Publishers, Boston and London, 1998 (pp. 367-396).

[0062] According to the present invention, unlike the illustration of FIG. 3, Steps 46 and 48 may be simultaneously performed. Alternatively, Step 48 may be followed by Step 46. In this case, Step 50 may be formed after Step 48 or may be at any time between Steps 42 through 48.

[0063] Hereinafter, embodiments of Step 50 of FIG. 3 and the downlink power control unit 84 of FIG. 4 according to the present invention will be described with reference to the appended drawings.

[0064] FIG. 11 is a flowchart illustrating an embodiment 50A of Step 50 of FIG. 3 according to the present invention. This embodiment 50A involves subtracting a second predetermined threshold value $SINR_{TH}$ from the SINR (Step 156) and determining the downlink power control information based on the sign of the subtracted result (Step 158).

[0065] FIG. 12 is a block diagram of an embodiment 84A of the downlink power control unit 84 of FIG. 4 according to the present invention. The embodiment 84A includes a subtraction portion 160 and a sign checking portion 162.

[0066] The subtraction portion 160 of FIG. 12 subtracts the second predetermined threshold value $SINR_{TH}$ from the SINR input from the channel characteristic determination unit 70 and outputs the subtracted result to the sign checking portion 162 (Step 156). After Step 156, the sign checking portion 162 determines the downlink power control information based on the sign of the subtracted result input from the subtraction portion 160 and outputs the determined downlink power control information C to the signal conversion unit 82 (Step 158). For example, if the SINR is determined to be greater than or equal to the second predetermined threshold value $SINR_{TH}$ from the subtracted result, in the sign checking portion 162, the downlink power control information c is set to 1. If the SINR is determined to be smaller than the second predetermined threshold value $SINR_{TH}$, in the sign checking portion 162, the downlink power control information c is set to -1. Here, c=1 means decreasing the downlink transmission power, and c=-1 means increasing the downlink transmission power.

[0067] After Step 50, the signal conversion unit 82 multiplexes the high-rate feedback information input from the high-rate feedback unit 76, the low-rate feedback information input from the low-rate feedback unit 78, and the downlink power control information input from the downlink power control unit 84 and outputs the multiplexed result to the antenna array 60 as the feedback signal suitable to be fed back (Step 52). The feedback signal input to the antenna array 60 is transmitted to the base station 10.

[0068] According to the present invention, the first mobile station 20, the second mobile station 22, or the X^{th} mobile station 24 may further include a signal restoration unit 80, as shown in FIG. 4. At any point of time during Steps 40 through 52, the signal restoration unit 80 restores original DPCH signals from the DPCH signals spatially processed in the base station 10 and received via the antenna array 60 and outputs restored DPCH signals, which will be denoted as DPCH'.

[0069] Hereinafter, embodiments of the base station 10 of FIG. 1 and Step 32 of FIG. 2 according to the present invention will be described with reference to the appended drawings.

[0070] FIG. 13 shows a flowchart illustrating an embodiment 32A of Step 32 of FIG. 2 according to the present invention. The embodiment 32A involves spatially processing the DPCH signals using restored long-term information, short-term information, and SINR (Steps 170 through 176) and adding pilot channel (PICH) signals to the spatially processed DPCH signals (Step 178).

[0071] FIG. 14 shows a block diagram of an embodiment of the base station 10 of FIG. 1 according to the present invention. In this embodiment, the base station 10 includes an information restoration unit 180, a basis information generation unit 182, a gain adjustment unit 184, a basis vector application unit 186, an addition unit 188, and an antenna array 190.

[0072] The antenna array 190 of FIG. 14, which includes *B* transmission antennas 192, 194, ..., 196, receives the feedback signal via an uplink dedicated physical control channel DPCCH from the first mobile station 22, the second mobile station 22, ..., or the X^{th} mobile station 24 and transmits the spatially processed DPCH signals and the PICH signals to the first mobile station 20, the second mobile station 22, ..., or the X^{th} mobile station 24.

[0073] After Step 30 of FIG. 2, the information restoration unit 180 restores the long-term information, effective short-term eigenvectors, and SINR from the feedback signal received via the antenna array 190 and outputs the restored long-term information, effective short-term eigenvectors, and SINR to the basis information generation unit 182 (Step 170). Since the long-term information and the effective short-term eigenvectors are output from the high-rate feedback unit 76 and the low-rate feedback unit 78 of FIG. 4 at low and high rates, respectively, via the signal conversion unit 82, the long-term information and short-term information are restored at low and high rates, respectively, by the information restoration unit 180.

[0074] After Step 170, the basis information generation unit 182 generates basis vectors **Q** and gain values $\mathbf{P}^{1/2}$ as basis information from the long-term information, effective short-term eigenvectors, and SINR restored by the information restoration unit 180 and outputs the generated gain values $\mathbf{P}^{1/2}$ to the gain adjustment unit 184 and the generated basis vectors **Q** to the basis vector application unit 186 (Step 172). Here, the basis vectors **Q** are in a $B \times N$ matrix, and the gain values $\mathbf{P}^{1/2}$ are in a $N \times 1$ matrix, wherein N indicates the number of basis vectors.

[0075] Hereinafter, embodiments of Step 172 of FIG. 13 and the basis information generation unit 182 of FIG. 14 according to the present invention will be described with reference to the appended drawings.

[0076] FIG. 15 shows a flowchart illustrating an embodiment 172A of Step 172 of FIG. 13 according to the present invention. The embodiment 172A involves interpolating the restored short-term information and generating effective short-term eigenvalues (Steps 200 and 202) and determining the basis vectors **Q** and gain values $\mathbf{P}^{1/2}$ from the long-term information and short-term information (Steps 204 through 208).

[0077] FIG. 16 shows a block diagram of an embodiment 182A of the basis information generation unit 182 of FIG. 14. The embodiment 182A includes a basis vector interpolation portion 220, a basis value generation portion 222, a first multiplication portion 224, a second multiplication portion 226, and a third eigenvalue decomposition and calculation portion 228.

[0078] After Step 170 of FIG. 13, the basis vector interpolation portion 220 interpolates the restored effective short-term eigenvectors $\mathbf{Q'}_{ST}$ input from the information restoration unit 180 and outputs the results of the interpolation, $\mathbf{Q'}_{ST0}$, to the first multiplication portion 224 (Step 200). This interpolation is performed based on the orthogonal relationship between the eigenvectors, using equation 7 below:

$$Q'_{ST0} = \lfloor\, Q'_{ST}\ q'_{ST,N_B} \rfloor \tag{7}$$

where $\mathbf{Q'}_{ST}$ can be expressed as equation 8 below, and the relationship of equation 9 is satisfied:

$$Q'_{ST} = [q'_{ST,0} \cdots q'_{ST,(N_B\text{-}1)}] \tag{8}$$

$$q'ST,N_B \cdot q'_{ST,N_B\text{-}1} = \ldots = q'_{ST,N_B} \cdot q'_{ST,1} \equiv 0 \tag{9}$$

[0079] After Step 200, the basis value generation portion 222 determines effective short-term eigenvalues Λ'_{ST} using a table T obtained from the restored signal to interference and noise ratio, SINR', and the number of effective long-term eigenvectors, N_B, input from the information restoration unit 180 and outputs the determined effective short-term eigenvalues Λ'_{ST} to the first multiplication portion 224 (Step 202). As described above, according to the present invention, although no effective short-term eigenvalues $_{\Lambda ST}$ are fed back from the mobile station 20, 22, ..., or 24 to the base station 10, the effective short-term eigenvalues Λ'_{ST} can be obtained from the restored signal to interference noise ratio SINR'.

[0080] FIG. 17 illustrates a table T used to determine the effective short-term eigenvalues Λ'_{ST} , in which the vertical axis denotes T values, in dB, and the horizontal axis denotes the number of effective long-term eigenvectors, N_B.

[0081] In an embodiment according to the present invention, the basis value generation portion 222 may store effective short-term eigenvalues Λ'_{ST} for various SINR' and number of effective long-term eigenvectors, N_B, for example, in a lookup table as shown in FIG. 17. In this case, effective short-term eigenvalues Λ'_{ST} are read according to the restored SINR' and the number of effective long-term eigenvectors, N_B and output to the first multiplication portion 224.

[0082] In another embodiment according to the present invention, the basis value generation portion 222 may calculate table $T(N_B)$ or $T(N_b,\gamma)$ from the SINR' and the number of effective long-term eigenvectors, N_B, using equation 10 or 11 below, instead of storing effective short-term eigenvalues in a lookup table.

$$T(N_B) = \frac{E[\mathbf{\Lambda}_{ST}(N_B)]}{\gamma}, \text{ where } \mathbf{\Lambda}_{ST}(N_B) = \begin{bmatrix} \lambda_{ST,1} & 0 & \cdots & 0 \\ 0 & \cdots & \cdots & 0 \\ 0 & 0 & \cdots & \lambda_{ST,N_B} \end{bmatrix} \quad \ldots(10)$$

$$T(N_B,\gamma) = \frac{E[\mathbf{\Lambda}_{ST}(N_B,\gamma)]}{\gamma}, \text{ where } \mathbf{\Lambda}_{ST}(N_B,\gamma) = \begin{bmatrix} \lambda_{ST,1}(\gamma) & 0 & \cdots & 0 \\ 0 & \cdots & \cdots & 0 \\ 0 & 0 & \cdots & \lambda_{ST,N_B}(\gamma) \end{bmatrix} \quad \ldots(11)$$

[0083] In equations 10 and 11 above, $E[\cdot]$ denotes an operator for the ensemble average, $\Lambda_{ST}(N_B)$ denotes a random variable diagonal matrix obtained from an arbitrary fourth characteristic $\mathbf{R}_{ST}$ by the EVD method when the number of short-term eigenvectors is equal to N_B , $\Lambda_{ST}(N_B,\gamma)$ denotes a random variable diagonal matrix obtained from an arbitrary fourth characteristic $\mathbf{R}_{ST}$ by the EVD method when the number of short-term eigenvectors is equal to N_B and the SINR' is γ. The effective short-term eigenvalues Λ'_{ST} can be expressed as equation 12 below from equation 10 for $\mathbf{T}(N_B)$ or equation 11 for $\mathbf{T}(N_B,\gamma)$ above:

$$\Lambda'_{ST}(N_B) = \gamma T(N_B) \text{ or } \Lambda'_{ST}(N_B,\gamma) = \gamma T(N_B,\gamma) \quad (12)$$

[0084] After Step 202, the first multiplication portion 224 multiplies the long-term information input from the information restoration unit 180, the results of the interpolation, $\mathbf{Q'}_{ST0}$, performed using the restored effective short-term eigenvectors and input from the basis vector interpolation portion 220, and the effective short-term eigenvalues Λ'_{ST} generated by the basis vector generation portion 222, as in equation 13 below, and outputs the product $\mathbf{W}^H$ to the second multiplication portion 226 as a reception channel characteristic matrix (Step 204). Here, the reception channel characteristic matrix $\mathbf{W}^H$ is a $B \times N_B$ matrix.

$$W^H = Q'_{LT}\, \Lambda'_{LT}{}^{1/2} Q'_{ST0}\, \Lambda'_{ST}{}^{1/2} \quad (13)$$

where $\mathbf{Q'}_{LT}$ and Λ'_{LT} denote the long-term information restored by the information restoration unit 180, and particularly, $\mathbf{Q'}_{LT}$ denotes restored effective long-term eigenvectors in a $B \times N_B$ matrix, and Λ'_{LT} denotes restored effective long-term eigenvalues in a $N_B \times N_B$ matrix, and $\mathbf{Q'}_{ST0}$ denotes interpolated restored effective short-term eigenvectors in a $N_B \times N_B$ matrix, and Λ'_{ST} denotes restored effective short-term eigenvalues in a $N_B \times N_B$ matrix.

[0085] After Step 204, the second multiplication portion 226 calculates an autocorrelation matrix **R'**, which corresponds to the complex product of the reception channel characteristic matrix $\mathbf{W}^H$ output from the first multiplication portion 224, using equation 14 below, and outputs the calculated autocorrelation matrix **R'** to the third eigenvalue decomposition and calculation portion 228 (Step 206). Here, the autocorrelation matrix **R'** is a $B \times B$ matrix.

$$R' = W^H W \quad (14)$$

[0086] After Step 206, the third eigenvalue decomposition and calculation portion 228 generates effective instantaneous eigenvectors, i.e., the basis vectors **Q,** and the gain values $\mathbf{P}^{1/2}$ from the autocorrelation matrix **R'** and outputs the results (Step 208).

[0087] Hereinafter, embodiments of Step 208 of FIG. 15 and the third eigenvalue decomposition and calculation portion 228 of FIG. 16 will be described with reference to the appended drawings.

[0088] FIG. 18 shows a flowchart illustrating an embodiment 208A of Step 208 of FIG. 15 according to the present invention. The embodiment 208A involves obtaining the basis vectors **Q** and the gain values $\mathbf{P}^{1/2}$ from instantaneous eigenvectors and eigenvalues (Steps 240 through 244).

[0089] FIG. 19 shows a block diagram of a preferred embodiment 228A of the third eigenvalue decomposition and calculation portion 228 of FIG. 16 according to the present invention which performs the embodiment 208A of FIG. 18.

The embodiment 228A of the third eigenvalue decomposition and calculation portion 228 includes a third eigenvalue decomposer 252, a power allocation portion 254, and a third selector 256.

[0090] After Step 206 of FIG. 15, the third eigenvalue decomposer 252 generates $B \times B$ instantaneous eigenvectors $\mathbf{Q}_0$ and $B \times B$ instantaneous eigenvalues Λ_0 from the autocorrelation matrix **R'** input from the second multiplication portion 226 by the above-described EVD method and outputs the generated $B \times B$ instantaneous eigenvectors $\mathbf{Q}_0$ to the third selector 256 and the generated $B \times B$ instantaneous eigenvalues Λ_0 to the power allocation portion 254 (Step 240).

[0091] After Step 240 of FIG. 18, the power allocation portion 254 generates the number of basis vectors, *N,* and the gain values $\mathbf{P}^{1/2}$ from the instantaneous eigenvalues Λ_0 input from the third eigenvalue decomposer 252 and outputs the generated number of basis vectors, *N,* to the third selector 256 and the generated gain values $\mathbf{P}^{1/2}$ to the gain adjustment unit 184 (Step 242). In particular, the power allocation portion 254 obtains a power allocation ratio for channels using the instantaneous eigenvalues Λ_0, allocates the total power given to the base station 10 among the channels using the obtained power allocation ratio, and determines the allocated results as the gain values $\mathbf{P}^{1/2}$. Here, the power allocation portion 254 may calculate the power allocation ratio and the number of basis vectors, *N,* from the instantaneous eigenvalues Λ_0 by a water filtering or inverse water filtering method. The water filtering method is disclosed in "Digital Baseband Transmission and Recording", *Jan W.M. Bergmans*, Kluwer Academic Press, Boston, 1996. The inverse water filtering method is disclosed in a Stanford University doctorial dissertation entitled "Linear precoding and decoding for multiple input multiple output (MIMO) wireless channels" by *Hemanth Sampath*, April, 2001.

[0092] After Step 242, the third selector 256 selects instantaneous eigenvectors in a quantity equal to the number of basis vectors, *N*, input from the power allocation portion 256, from among the instantaneous eigenvectors $\mathbf{Q}_0$ input from the third eigenvalue decomposer 252 and outputs column vectors which consist of the selected *N* instantaneous eigenvectors, as the effective instantaneous eigenvectors, i.e., the basis vectors **Q,** to the basis vector application unit 186 (Step 244). Here, the size of the column vectors is *N.*

[0093] After Step 172 of FIG. 13, the gain adjustment unit 184 adjusts the amplitudes of the DPCH signals according to the *N* gain values $\mathbf{P}^{1/2}$ input from the basis information generation unit 182 and outputs the amplitude-adjusted DPCH signals to the basis vector application unit 186 (Step 174).

[0094] Hereinafter, an embodiment of Step 174 of FIG. 13 according to the present invention will be described with reference to the appended drawings.

[0095] FIG. 20 shows a flowchart illustrating an embodiment 174A of Step 174 of FIG. 13 according to the present invention. The embodiment 174A involves adjusting modulation orders, coding rates, and amplitudes of the DPCH signals (Step 260), and spreading and scrambling the DPCH signals having the adjusted results (Step 262).

[0096] Referring to FIG. 20, after Step 172, the modulation orders, coding rates, and amplitudes of the DPCH signals are adjusted (Step 260).

[0097] Hereinafter, embodiments of Step 260 of FIG. 20 and the gain adjustment unit 184 of FIG. 14 according to the present invention will be described with reference to the appended drawings.

[0098] FIG. 21 shows a flowchart illustrating an embodiment 260A of Step 260 of FIG. 20. The embodiment 260A involves multiplying DPCH signals modulated with the modulation orders calculated using the gain values, by the gain values (Steps 270 through 274).

[0099] FIG. 22 shows a block diagram of a preferred embodiment 184A of the gain adjustment unit 184 of FIG. 14. The embodiment 184A of the gain adjustment unit 184 includes a controller 280, P_1-order, P_2-order, ..., and P_{N_B} -order modulators 282, 284, ... and 286, first, second, ..., and N_Bth multipliers 290, 292, ..., and 294, and a $(N_B + 1)$th multiplier 300.

[0100] After Step 172, the controller 280 calculates the modulation orders for the P_1-order, P_2-order, ..., and P_{N_B} -order modulators 282, 284, ..., and 286 using the gain values $\mathbf{P}^{1/2}$ input from the basis information generation unit 182 by linear proportion and outputs the calculated modulation orders to the respective P_1-order, P_2-order, ..., and P_{N_B} -order modulators 282, 284, ..., and 286 (Step 270). The controller 280 checks for the quantity of power allocated to each channel using the gain values $\mathbf{P}^{1/2}$ and determines the modulation order for each channel in proportional to the quantity of power allocated to each channel. The controller 280 assigns the largest modulation order to the channel to which the greatest power is allocated and the lowest modulation order to the channel to which the lowest power is allocated.

[0101] After Step 270, P_1-order, P_2-order, ..., and P_{N_B} -order modulators 282, 284, ..., and 286 perform P_1-order, P_2-order, ..., and P_{N_B} -order quadrature amplitude modulation (QAM) on the DPCH signals according to the modulation orders input from the controller 280 and output the modulated results to the respective first, second, ..., and N_Bth multipliers 290, 292, ... and 294 (Step 272). Alternatively, the P_1-order, P_2-order, ..., and P_{N_B} -order modulators 282, 284, ..., and 286 may modulate the DPCH signals by an adaptive modulation and coding (AMC) method. The AMC method is disclosed in an article entitled "Variable-Rate Variable-Power MQAM for Fading Channels", IEEE Trans. On communications Vol. 45, No. 10, October, 1997, by *A. Goldsmith* and *S. Chua.,* October, 1997.

[0102] After Step 272, the first, second, ..., and N_Bth multipliers 290, 292, ..., and 294 multiply the modulated results output from the respective P_1-order, P_2-order, ..., and P_{N_B}-order modulators 282, 284, ..., and 286 by the gain values $\mathbf{P}^{1/2}$ and output the products to the $(N_B+1)^{th}$ multiplier 300 (Step 274).

[0103] The controller 280, the P_1-order, P_2-order, ..., and P_{N_B}-order modulators 282, 284, ..., and 286, and the first, second, ..., and N_B^{th} multipliers 290, 292, ..., and 294 perform Step 260 of FIG. 20 or Step 260A of FIG. 21.

[0104] Referring to FIG. 20, after Step 260, the $(N_B+1)^{th}$ multiplier 300 multiplies the products output from the first, second, ..., and N_B^{th} multipliers 290, 292, ..., and 294 by scramble/spread signal streams and outputs the products as the DPCH signals having adjusted amplitudes via an output port OUT1 to the basis vector application unit 186 (Step 262). Here, scramble/spread signal streams, expressed as $C_{SP}C_{SC}$, refer to the products of multiplying scramble signal streams C_{SC} by spread signal streams C_{SP}. Although the scramble/spread signal streams are illustrated as being previously stored in the gain adjustment unit 184 of FIG. 14, the scramble/spread signal streams may be externally input, unlike the illustration of FIG. 14.

[0105] According to the present invention, in the gain adjustment unit 184A of FIG. 22, the $(N_B+1)^{th}$ multiplier 300 may be optional. When Step 262 is omitted, i.e., when the gain adjustment unit 184A does not include the $(N_B+1)^{th}$ multiplier 300, the products of the multiplication by the first, second, ..., and N_B^{th} multipliers 290, 292, ..., and 294 are output to the basis vector application unit 186 as the DPCH signals having adjusted amplitudes.

[0106] After Step 174 of FIG. 13, the basis vector application unit 186 applies the basis vectors Q input from the basis information generation unit 182 to the amplitude-adjusted DPCH signals input from the gain adjustment unit 184 and outputs the results to the addition unit 188 as spatially processed DPCH signals (Step 176).

[0107] FIG. 23 shows a block diagram of an embodiment 186A of the basis vector application unit 186 of FIG. 14 according to the present invention. The embodiment 186A of the basis vector application unit 186 includes a $(N_B+2)^{th}$ multiplier 310.

[0108] To perform Step 176, the $(N_B+2)^{th}$ multiplier 310 of the basis vector application unit 186A multiplies the N_B DPCH signals $\mathbf{i}$ having the adjusted amplitudes input via an input port IN2 from the gain adjustment unit 184 by the basis vectors Q input from the basis information generation unit 182, as expressed in equation 15 below, and outputs the products via the output port OUT2 to the addition unit 188 as the spatially processed DPCH signals $\mathbf{o}$:

$$o = Qi \tag{15}$$

where $\mathbf{o}$ and $\mathbf{i}$ are expressed as equations 16 and 17, respectively, below.

$$o = [\, o_1 \; o_2 \cdots o_B] \tag{16}$$

$$i = [\, i_1 \; i_2 \cdots i_N \,] \tag{17}$$

[0109] After Step 176, the addition unit 188 adds PICH signals $P_1(k)$, $P_2(k)$, $P_3(k)$, ..., and $P_B(k)$ input via an input port IN1 to the spatially processed DPCH signals input from the basis vector application unit 186 and transmits the added results via the antenna array 190 including transmission antennas to the first mobile station 20, the second mobile station 22, ..., or the X^{th} mobile station 24 (Step 178).

[0110] To perform Step 178, the addition unit 188 may include B adders (not shown). Here, the adders add the corresponding PICH signals $P_1(k)$, $P_2(k)$, $P_3(k)$, ..., and $P_B(k)$ to the spatially processed DPCH signals input from the basis vector application unit 186, respectively, and output the added results to the respective transmission antennas 192, 194, ..., and 196 of the antenna array 190. The transmission antennas 192, 194, ..., and 196 transmit the added results by the corresponding adders (not shown) of the addition unit 188 to the corresponding mobile stations 20, 22, ..., and 24.

[0111] The embodiments of the base station 10 of FIG. 1 and Step 32 are not limited to the above-described embodiments of the mobile station 10 and Step 30 and can be applied to any mobile station capable of generating long-term information and short-term information and converting them into a feedback signal and capable of transmitting the feedback signal to the base station 10, as described above.

[0112] As described above, in the mobile communication apparatus including multiple transmission and reception antennas and the mobile communication method performed in the apparatus according to the present invention, the long-term information and short-term information reflecting the spatial-channel downlink characteristic are fed back from the mobile station to the base station, wherein only effective short-term eigenvectors, excluding effective short-term eigenvalues, are fed back as the short-term information. Therefore, with the great advantage of closed communications systems, the effects of interference, noise, and fading can be minimized, whereas throughput can be maximized.

[0113] While the present invention has been particularly shown and described with reference to preferred embodiments thereof, it will be understood by those of ordinary skill in the art that various changes in form and details may be made therein without departing from the scope of the present invention as defined by the appended claims.

Claims

1. A mobile communication apparatus with multiple transmission and reception antennas, the apparatus comprising a base station and a mobile station,
wherein:

the base station with at least one transmission antenna is arranged to restore long-term information, short-term information and a signal to interference and noise ratio (SINR) from a feedback signal received from the mobile station, spatially processes dedicated physical channel (DPCH) signals using basis information generated from the restored long-term information, short-term information, and SINR and transmits the results of adding pilot channel (PICH) signals to the spatially processed results to the mobile station;
the mobile station with at least one reception antenna is arranged to determine a first characteristic corresponding to the channel downlink characteristic for each of the transmission and reception antennas, from the PICH signals transmitted from the base station, determines the long-term information, the short-term information, and downlink power control information including the SINR, which reflect the first characteristic, converts the determined long-term information, short-term information, and downlink power control information into the feedback signal, and transmits the feedback signal to the base station; and
the long-term information includes effective long-term eigenvectors and effective long-term eigenvalues, the short-term information includes effective short-term eigenvectors, and the downlink power control information indicates whether to increase or decrease downlink transmission power.

2. The mobile communication apparatus of claim 1, wherein the mobile station comprises:

a channel characteristic determination unit which determines the first characteristic from the PICH signals received via the at least one reception antenna, determines a second characteristic from the first characteristic, and generates the SINR from the generated second characteristic;
a long-term information determination unit which determines the effective long-term eigenvectors and the effective long-term eigenvalues using the second characteristic input from the channel characteristic determination unit;
a short-term information determination unit which determines the effective short-term eigenvectors using the second characteristic input from the channel characteristic determination unit and the long-term information;
a high-rate feedback unit which encodes the effective short-term eigenvectors input from the short-term information determination unit as bits and outputs the result of the bit encoding at first predetermined time intervals as high-rate feedback information;
a low-rate feedback unit which encodes the long-term information input from the long-term information determination unit as bits and outputs the result of the bit encoding at second predetermined time intervals as low-rate feedback information;
a downlink power control unit which generates the downlink power control information from the SINR generated by the channel characteristic determination unit and outputs the generated downlink power control information; and
a signal conversion unit which multiplexes the high-rate feedback information, the low-rate feedback information, and the downlink power control information and outputs the multiplexed result to the at least one reception antenna as the feedback signal,

wherein the second characteristic corresponds to an instantaneous correlation of the channel downlink characteristic for each of the transmission and reception antennas, the reception antenna transmits the feedback signal to the base station, and the first predetermined time interval is shorter than the second predetermined time interval.

3. The mobile communication apparatus of claim 2, wherein the mobile station further comprises a signal restoration unit which restores the DPCH signals from the spatially processed results received via the at least one reception antenna and outputs the restored DPCH signals.

4. The mobile communication apparatus of claim 2 or 3, wherein the long-term information determination unit comprises:

an accumulation portion which accumulates the second characteristic input from the channel characteristic determination unit and outputs the accumulated result as a third characteristic; and
a first eigenvalue decomposition and calculation portion which generates the effective long-term eigenvectors and the effective long-term eigenvalues from the third characteristic by an eigenvalue decomposition method,

wherein the third characteristic corresponds to a long-term correlation of the channel downlink characteristic for each of the transmission and reception antennas.

5. The mobile communication apparatus of claim 4, wherein the first eigenvalue decomposition and calculation portion comprises:

a first eigenvalue decomposer which generates long-term eigenvectors and long-term eigenvalues using the third characteristic input from the accumulation portion by the eigenvalue decomposition method;
a vector counter which counters the number of long-term eigenvalues which are greater than a first predetermined threshold value and outputs the counted result as the number of effective long-term eigenvectors; and
a first selector which selects long-term eigenvectors from which noises have been removed, in a quantity equal to the number of transmission antennas from among the long-term eigenvectors input from the first eigenvalue decomposer, selects long-term eigenvalues from which noises have been removed, in a quantity equal to the number of effective long-term eigenvectors from among the long-term eigenvalues input from the first eigenvalue decomposer, and outputs the selected long-term eigenvectors and long-term eigenvalues as the effective long-term eigenvectors and the effective long-term eigenvalues, respectively,

wherein the first predetermined threshold value means a noise level in the third characteristic.

6. The mobile communication apparatus of any one of claims 2 to 5,
wherein the short-term information determination unit comprises:

a short-term correlation determination portion which determines a fourth characteristic using the second characteristic input from the channel characteristic determination unit and the long-term information and outputs the fourth characteristic; and
a second eigenvalue decomposition and calculation portion which generates the effective short-term eigenvectors from the fourth characteristic by an eigenvalue decomposition method and outputs the generated effective short-term eigenvectors,

wherein the fourth characteristic corresponds to a short-term correlation of the channel downlink characteristic for each of the transmission and reception antennas.

7. The mobile communication apparatus of claim 6, wherein the second eigenvalue decomposition and calculation portion comprises:

a second eigenvalue decomposer which generates short-term eigenvectors using the fourth characteristic input from the short-term correlation determination portion by the eigenvalue decomposition method; and
a second selector which selects N_B x(N_B -1) short-term eigenvectors from among the short-term eigenvectors input from the second eigenvalue decomposer and outputs the selected short-term eigenvectors as the effective short-term eigenvectors, wherein N_B corresponds to the number of effective long-term eigenvectors.

8. The mobile communication apparatus of any one of claims 2 to 7,
wherein the downlink power control unit comprises:

a subtraction portion which subtracts a second predetermined threshold value from the SINR input from the channel characteristic determination unit and outputs the subtracted result; and
a sign checking portion which determines the downlink power control information based on the sign of the subtracted result input from the subtraction portion and outputs the determined downlink power control information to the signal conversion unit.

9. The mobile communication apparatus of any one of claims 1 to 8, wherein the base station comprises:

an information restoration unit which restores the long-term information, the effective short-term eigenvectors, and the SINR from the feedback signal received via the at least one transmission antenna and outputs the restored long-term information, effective short-term eigenvectors and SINR;
a basis information generation unit which generates basis vectors and gain values as basis information from the restored long-term information, effective short-term eigenvectors and SINR;
a gain adjustment unit which adjusts the amplitudes of the DPCH signals according to the gain values and outputs the adjusted results;
a basis vector application unit which applies the basis vectors to the adjusted results input from the gain adjustment unit and outputs the results as the spatially processed results; and
an addition unit which adds the PICH signals to the spatially adjusted results and outputs the added results,

wherein the at least one transmission antennas transmits the added results to the mobile station.

10. The mobile communication apparatus of claim 9, wherein the basis information generation unit comprises:

a basis vector interpolation portion which interpolates the restored effective short-term eigenvectors input from the information restoration unit;
a basis value generation portion which determines effective short-term eigenvalues using a table obtained from the restored SINR input from the information restoration unit and the number of effective long-term eigenvectors, N_B ;
a first multiplication portion which multiplies the restored long-term information, the result of the interpolation performed using the effective short-term eigenvectors, and the generated effective short-term eigenvalues, and outputs the product;
a second multiplication portion which calculates an autocorrelation matrix using the product from the first multiplication portion and outputs the calculated autocorrelation matrix; and
a third eigenvalue decomposition and calculation portion which generates the basis vectors and the gain values using the autocorrelation matrix input from the second multiplication portion.

11. The mobile communication apparatus of claim 10, wherein the third eigenvalue decomposition and calculation portion comprises:

a third eigenvalue decomposer which generates instantaneous eigenvectors and instantaneous eigenvalues from the autocorrelation matrix input from the second multiplication portion by an eigenvalue decomposition method;
a power allocation portion which generates the number of basis vectors and the gain values from the instantaneous eigenvalues input from the third eigenvalue decomposer; and
a third selector which selects instantaneous eigenvectors in a quantity equal to the number of basis vectors input from the power allocation portion, from among the instantaneous eigenvectors input from the third eigenvalue decomposer, and outputs column vectors which consist of the selected instantaneous eigenvectors, as the basis vectors.

12. The mobile communication apparatus of claim 10 or 11, wherein the first multiplication portion multiplies the restored long-term information, the results of the interpolation performed using the effective short-term eigenvectors, $\mathbf{Q'}_{ST0}$, and the generated effective short-term eigenvalues Λ'_{ST} using the following equation and outputs the product $\mathbf{W}^H$ to the second multiplication portion:

$$W^H = Q'_{LT}\, \Lambda'_{LT}{}^{1/2}\, Q'_{ST0}\, \Lambda'_{ST}{}^{1/2}$$

where $\mathbf{Q'}_{LT}$ and Λ'_{LT} denote the restored effective long-term eigenvectors and effective long-term eigenvalues, respectively, as the restored long-term information.

13. The mobile communication apparatus of claim 11, wherein the power allocation portion calculates a power allocation ratio for channels and the number of basis vectors from the instantaneous eigenvalues by a water filtering or inverse water filtering method, allocates the total power given to the base station among the channels using the power allocation ratio, and determines the allocated results as the gain values.

14. The mobile communication apparatus of any one of claims 9 to 13, wherein the gain adjustment unit comprises:

a controller which calculates modulation orders using the gain values by linear proportion and outputs the calculated modulation orders;
P_1-order, P_2-order, ..., and P_{N_B} -order modulators which modulate the DPCH signals according to the modulation orders input from the controller and output each modulated result, where N_B means the number of effective long-term eigenvectors; and
first, second, ..., and N_B^{th} multipliers which multiply the modulated results from the respective P_1-order, P_2-order, ..., and P_{N_B} -order modulators by the gain values and outputs the products as the gain-adjusted results.

15. The mobile communication apparatus of claim 14, wherein P_1-order, P_2-order, ..., and P_{N_B} -order modulators modulate the DPCH signals according to the modulation orders by quadrature amplitude modulation (QAM).

16. The mobile communication apparatus of claim 14 or 15, wherein the gain adjustment unit further comprises a $(N_B +1)^{th}$ multiplier which multiplies the products from the first, second, ..., and N_B th multipliers by scramble/spread signal streams and outputs the products to the basis vector application unit as the amplitude-adjusted results.

17. The mobile communication apparatus of any one of claims 9 to 16, wherein the basis vector application unit comprises a $(N_B +2)^{th}$ multiplier which multiplies the amplitude-adjusted results input from the gain adjustment unit by the basis vectors input from the basis information generation unit and outputs the products as the spatially adjusted results.

18. A mobile communication method performed between a base station with at least one transmission antenna and a mobile station with at least one reception antenna, the method comprising a step of (a) restoring long-term information, short-term information and a signal to interference and noise ratio (SINR) determined in the mobile station reflecting a first characteristic corresponding to a channel downlink characteristic for each of the transmission and reception antennas, from a feedback signal received from the mobile station, spatially processing dedicated physical channel (DPCH) signals using basis information generated from the restored long-term information, short-term information and SINR, adding pilot channel (PICH) signals to the spatially processed results, and transmitting the added results to the mobile station,

wherein the long-term information includes effective long-term eigenvectors and effective long-term eigenvalues, and the short-term information includes effective short-term eigenvectors.

19. The mobile communication method of claim 18, further comprising (b) determining the first characteristic from the PICH signals transmitted from the base station, determining the long-term information, the short-term information, and downlink power control information including the SINR, based on the first characteristic, converts the determined long-term information, short-term information and downlink power control information into the feedback signal, and transmitting the feedback signal to the base station, wherein the downlink power control information includes information as to whether to increase or decrease downlink transmission power.

20. The mobile communication method of claim 19, wherein step (a) comprises the steps of:

(a1) restoring the long-term information, the effective short-term eigenvectors, and the SINR from the feedback signal which is received via the at least one transmission antenna;
(a2) generating basis vectors and basis values as basis information from the restored long-term information, effective short-term eigenvectors and SINR;
(a3) adjusting the amplitudes of the DPCH signals using the gain values;
(a4) applying the basis vectors to the amplitude-adjusted DPCH signals and determining the results as the spatially processed results; and
(a5) adding the PICH signals to the spatially processed results and transmitting the added results via the at least one transmission antenna to the mobile station.

21. The mobile communication method of claim 20, wherein step (a2) comprises the steps of:

(a21) after step (a1), interpolating the restored effective short-term eigenvectors;

(a22) determining effective short-term eigenvalues using a table obtained from the restored SINR and the number of effective long-term eigenvectors, N_B ;
(a23) multiplying the restored long-term information, the results of the interpolation performed using the effective short-term eigenvectors; and the effective short-term eigenvalues to obtain a reception channel characteristic matrix;
(a24) calculating an autocorrelation matrix from the reception channel characteristic matrix; and
(a25) generating the basis vectors and the gain values from the autocorrelation matrix and proceeding to step (a3).

22. The mobile communication method of claim 21, wherein step (a25) comprises:

after step (a24), generating instantaneous eigenvectors and instantaneous eigenvalues from the autocorrelation matrix by an eigenvalue decomposition method;
generating the number of basis vectors, N, and the gain values from the instantaneous eigenvectors; and
selecting instantaneous eigenvectors in a quantity equal to the number of basis vectors, *N,* from among the generated instantaneous eigenvectors, and determining the selected *N* instantaneous eigenvectors as the basis vectors.

23. The mobile communication method of any one of claims 20 to 22, wherein step (a3) comprises (a31) adjusting the modulation orders, coding rates, and amplitudes of the DPCH signals using the gain values after step (a2) and proceeding to step (a4).

24. The mobile communication method of claim 23, wherein step (a3) further comprises (a32) multiplying the adjusted results in step (a31) by scramble/spread signal streams, determining the products as DPCH signals having adjusted amplitudes, and proceeding to step (a4).

25. The mobile communication method of claim 23 or 24, wherein step (a31) comprises:

after step (a2), obtaining the modulation orders using the gain values by linear proportion; and
modulating the DPCH signals according to the modulation orders; and
multiplying the modulated results by the gain values and proceeding to step (a4).

26. The mobile communication method of any one of claims 20 to 25,
wherein step (a4) comprises multiplying the DPCH signals having adjusted amplitudes obtained in step (a3) by the basis vectors, determining the products as the spatially processed results, and proceeding to step (a5).

27. The mobile communication method of any one of claims 19 to 26,
wherein step (b) comprises:

(b1) determining the first characteristic from the PICH signals received via the at least one reception antenna, generating a second characteristic using the determined first characteristic, and determining the SINR from the generated second characteristic;
(b2) determining the effective long-term eigenvectors and the effective long-term eigenvalues using the second characteristic;
(b3) determining the effective short-term eigenvectors using the second characteristic and the long-term information;
(b4) encoding the effective short-term eigenvectors as bits and determining the result of the bit encoding as high-rate feedback information;
(b5) encoding the long-term information as bits and determining the result of the bit encoding as low-rate feedback information;
(b6) generating the downlink power control information using the SINR; and
(b7) converting the high-rate feedback information, the low-rate feedback information, and the downlink power control information into the feedback signal and transmitting the converted feedback signal via the at least one reception antenna to the base station,
wherein the second characteristic corresponds to an instantaneous correlation of the channel downlink characteristic for each of the transmission and reception antennas.

28. The mobile communication method of claim 27, wherein step (b6) comprises:

after step (b5), subtracting a second predetermined threshold value from the SINR; and
determining the downlink power control information based on the sign of the subtracted result and proceeding to step (b7).

29. The mobile communication method of claim 27 or 28, wherein step (b) further comprises restoring the PICH signals from the spatially processed results received via the at least one reception antenna.

30. The mobile communication method of any one of claims 27 to 29, wherein step (b2) comprises:

(b21) after step (b1), accumulating the second characteristic and determining the accumulated result as a third characteristic; and
(b22) generating the effective long-term eigenvactors and the effective long-term eigenvalues from the third characteristic by an eigenvalue decomposition method and proceeding to step (b3),
wherein the third characteristic corresponds to a long-term correlation of the channel downlink characteristic for each of the transmission and reception antennas.

31. The mobile communication method of claim 30, wherein step (b22) comprises:

after step (b21), generating long-term eigenvectors and long-term eigenvalues from the third characteristic by the eigenvalue decomposition method;
counting the number of long-term eigenvalues which are greater than a first predetermined threshold value and determining the counted result as the number of effective long-term eigenvectors; and
selecting long-term eigenvectors from which noises have been removed, in a quantity equal to the number of transmission antennas from among the generated long-term eigenvectors, selecting long-term eigenvalues from which noises have been removed, in a quantity equal to the number of effective long-term eigenvectors from among the generated long-term eigenvalues, outputting the selected long-term eigenvectors and long-term eigenvalues as the effective long-term eigenvectors and the effective long-term eigenvalues, respectively, and proceeding step (b3),

wherein the first predetermined threshold value means a noise level in the third characteristic.

32. The mobile communication method of any one of claims 27 to 31, wherein step (b3) comprises:

(b31) after step (b2), generating a fourth characteristic using the second characteristic and the long-term information; and
(b32) generating the effective short-term eigenvectors from the fourth characteristic by an eigenvalue decomposition method and proceeding to step (b4),
wherein the fourth characteristic corresponds to a short-term correlation of the channel downlink characteristic for each of the transmission and reception antennas.

33. The mobile communication method of claim 32, wherein step (b32) comprises:

after step (b31), generating short-term eigenvectors using the fourth characteristic by the eigenvalue decomposition method; and
selecting N_B x(N_B -1) short-term eigenvectors from among the short-term eigenvectors as the effective short-term eigenvectors, wherein N_B corresponds to the number of effective long-term eigenvectors.

FIG. 1

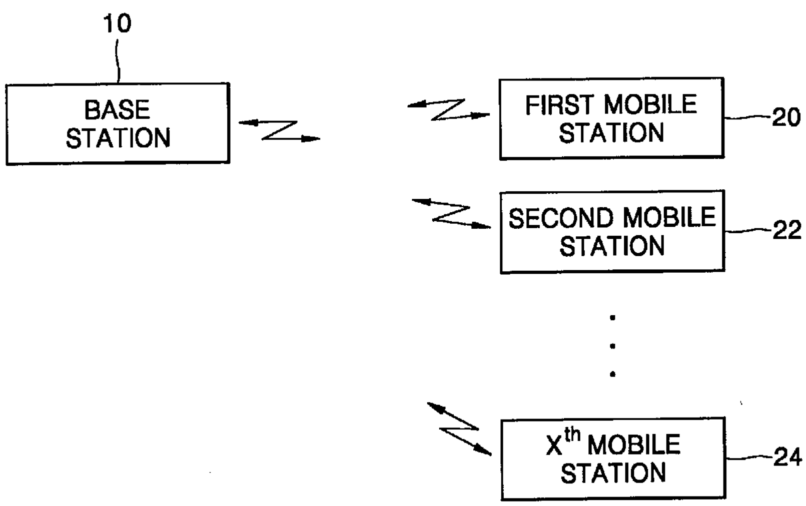

10
BASE STATION
FIRST MOBILE STATION
20
SECOND MOBILE STATION
22
X^th MOBILE STATION
24

FIG. 2

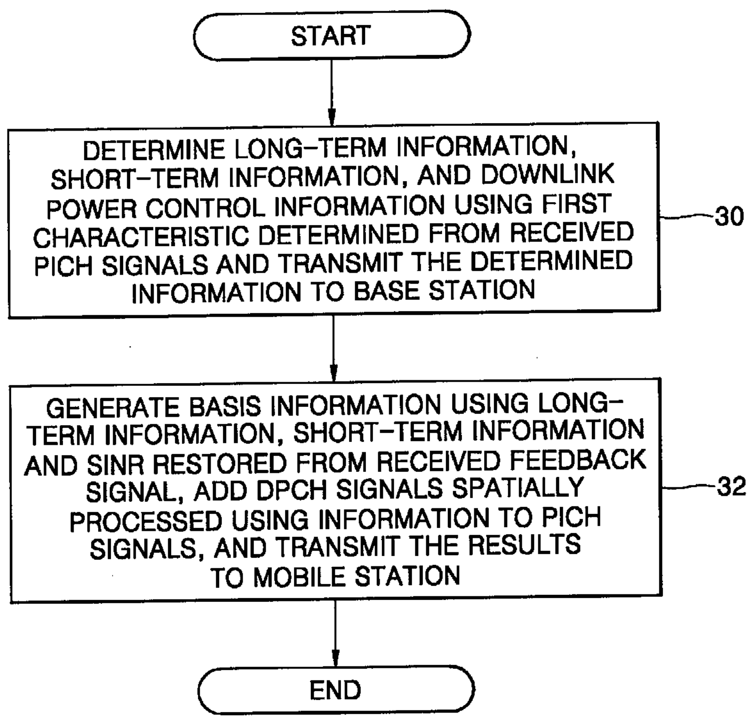

START
DETERMINE LONG-TERM INFORMATION, SHORT-TERM INFORMATION, AND DOWNLINK POWER CONTROL INFORMATION USING FIRST CHARACTERISTIC DETERMINED FROM RECEIVED PICH SIGNALS AND TRANSMIT THE DETERMINED INFORMATION TO BASE STATION
30
GENERATE BASIS INFORMATION USING LONG-TERM INFORMATION, SHORT-TERM INFORMATION AND SINR RESTORED FROM RECEIVED FEEDBACK SIGNAL, ADD DPCH SIGNALS SPATIALLY PROCESSED USING INFORMATION TO PICH SIGNALS, AND TRANSMIT THE RESULTS TO MOBILE STATION
32
END

FIG. 3

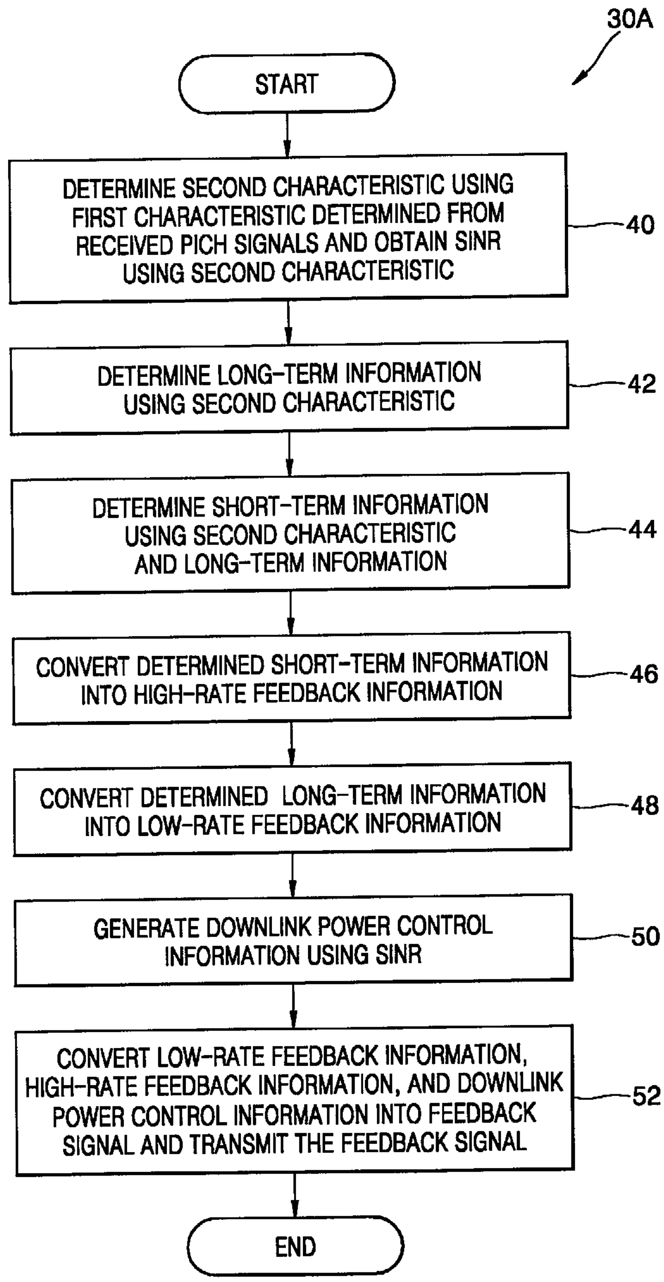

30A
START
DETERMINE SECOND CHARACTERISTIC USING FIRST CHARACTERISTIC DETERMINED FROM RECEIVED PICH SIGNALS AND OBTAIN SINR USING SECOND CHARACTERISTIC
40
DETERMINE LONG-TERM INFORMATION USING SECOND CHARACTERISTIC
42
DETERMINE SHORT-TERM INFORMATION USING SECOND CHARACTERISTIC AND LONG-TERM INFORMATION
44
CONVERT DETERMINED SHORT-TERM INFORMATION INTO HIGH-RATE FEEDBACK INFORMATION
46
CONVERT DETERMINED LONG-TERM INFORMATION INTO LOW-RATE FEEDBACK INFORMATION
48
GENERATE DOWNLINK POWER CONTROL INFORMATION USING SINR
50
CONVERT LOW-RATE FEEDBACK INFORMATION, HIGH-RATE FEEDBACK INFORMATION, AND DOWNLINK POWER CONTROL INFORMATION INTO FEEDBACK SIGNAL AND TRANSMIT THE FEEDBACK SIGNAL
52
END

FIG. 4

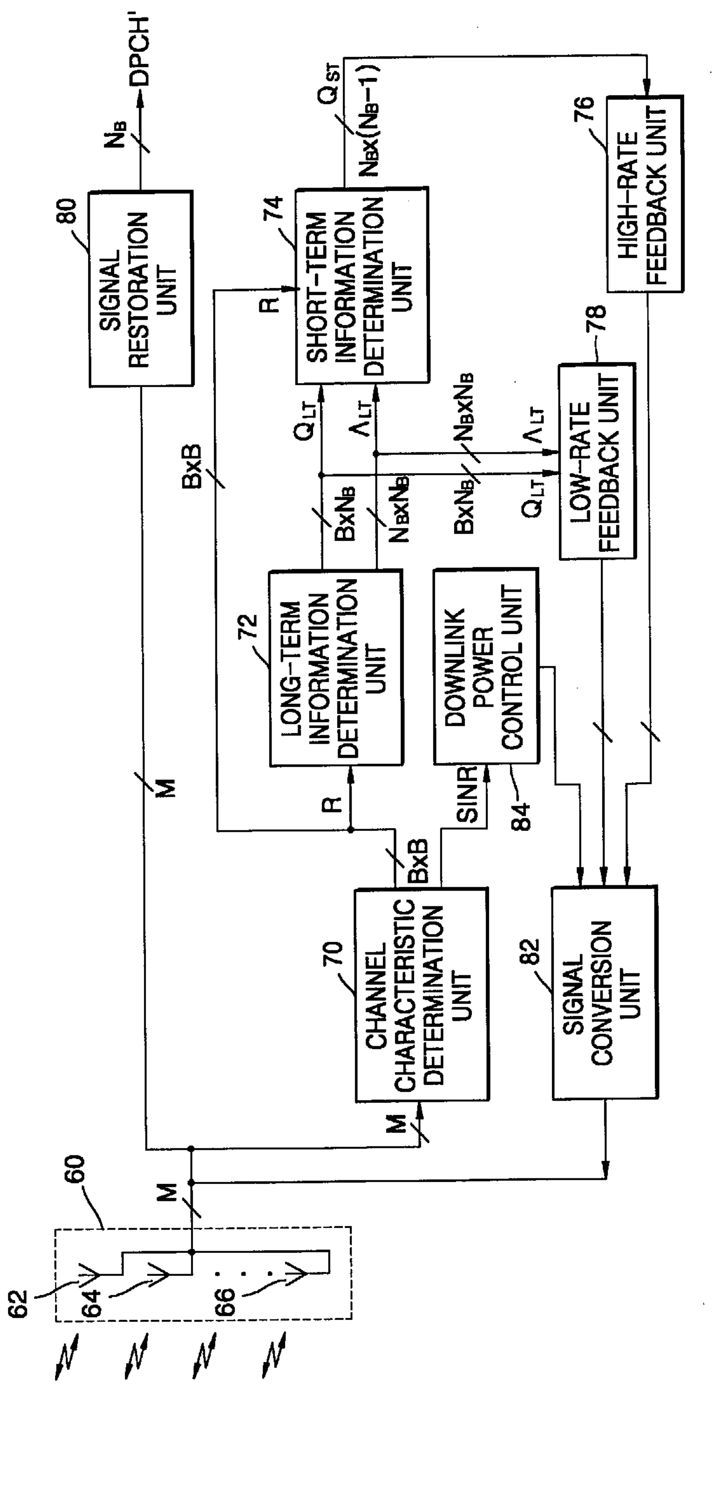

SIGNAL RESTORATION UNIT
80
N_B
DPCH'
SHORT-TERM INFORMATION DETERMINATION UNIT
74
Q_{ST}
N_Bx(N_B-1)
76
HIGH-RATE FEEDBACK UNIT
R
Q_{LT}
Λ_{LT}
BxB
BxNB
NBxNB
78
LOW-RATE FEEDBACK UNIT
LONG-TERM INFORMATION DETERMINATION UNIT
72
DOWNLINK POWER CONTROL UNIT
84
SINR
M
CHANNEL CHARACTERISTIC DETERMINATION UNIT
70
SIGNAL CONVERSION UNIT
82
60
62
64
66

FIG. 5

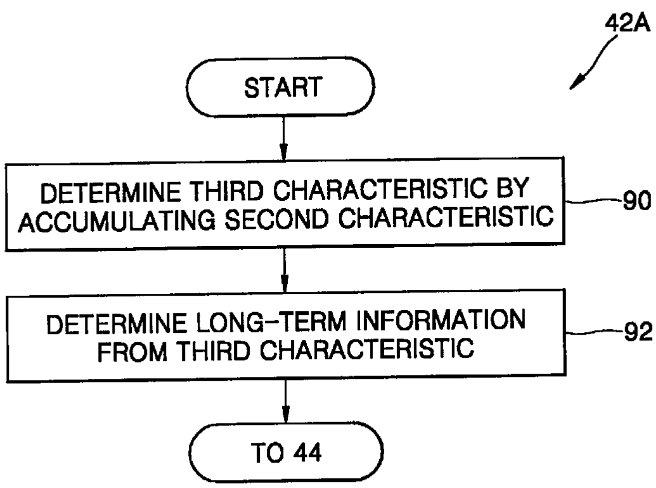

42A
START
DETERMINE THIRD CHARACTERISTIC BY ACCUMULATING SECOND CHARACTERISTIC
90
DETERMINE LONG-TERM INFORMATION FROM THIRD CHARACTERISTIC
92
TO 44

FIG. 6

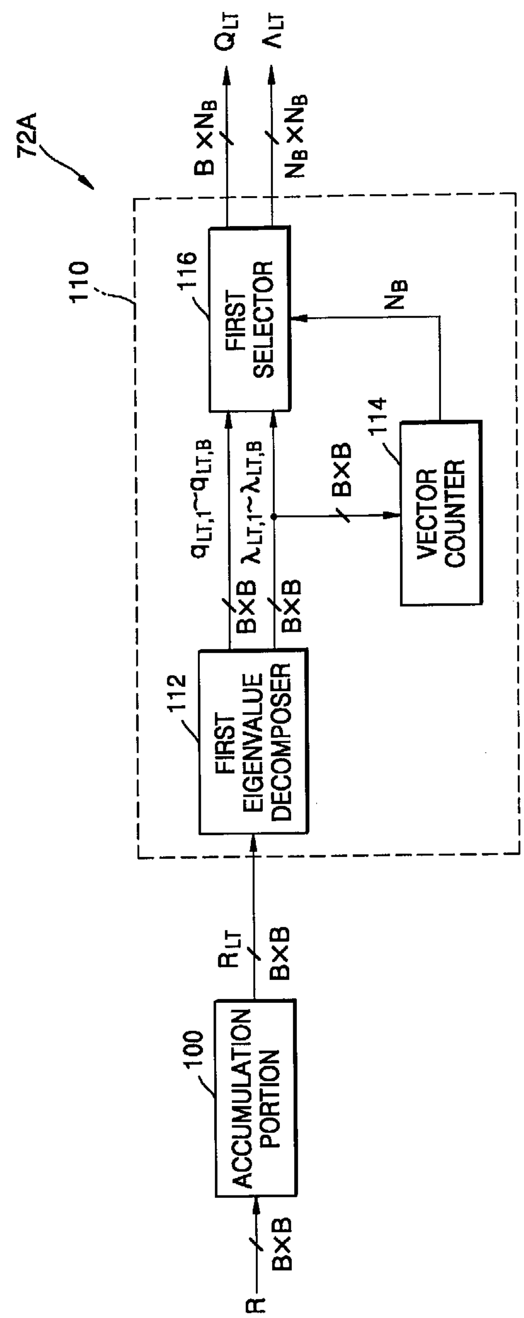

72A
110
R
B×B
100
ACCUMULATION PORTION
R_{LT}
B×B
112
FIRST EIGENVALUE DECOMPOSER
B×B
B×B
$q_{LT,1}$~$q_{LT,B}$
$\lambda_{LT,1}$~$\lambda_{LT,B}$
B×B
114
VECTOR COUNTER
N_B
116
FIRST SELECTOR
B ×N_B
N_B ×N_B
Q_{LT}
Λ_{LT}

FIG. 7

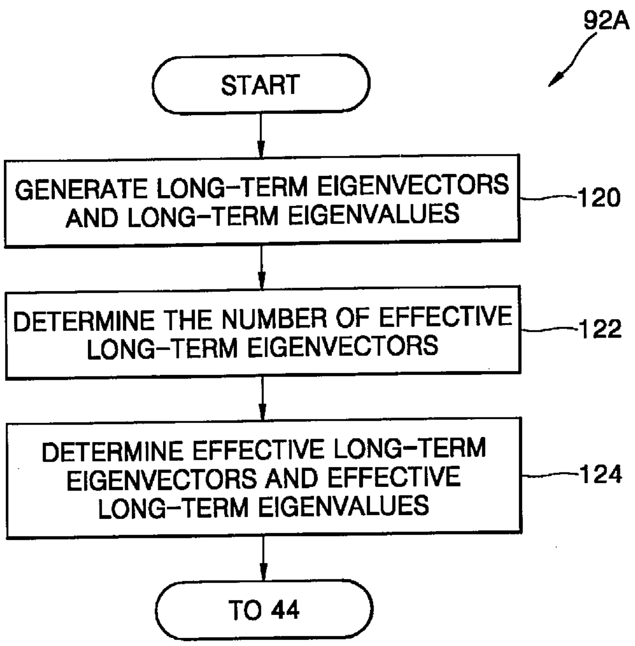

92A
START
GENERATE LONG-TERM EIGENVECTORS AND LONG-TERM EIGENVALUES
120
DETERMINE THE NUMBER OF EFFECTIVE LONG-TERM EIGENVECTORS
122
DETERMINE EFFECTIVE LONG-TERM EIGENVECTORS AND EFFECTIVE LONG-TERM EIGENVALUES
124
TO 44

FIG. 8

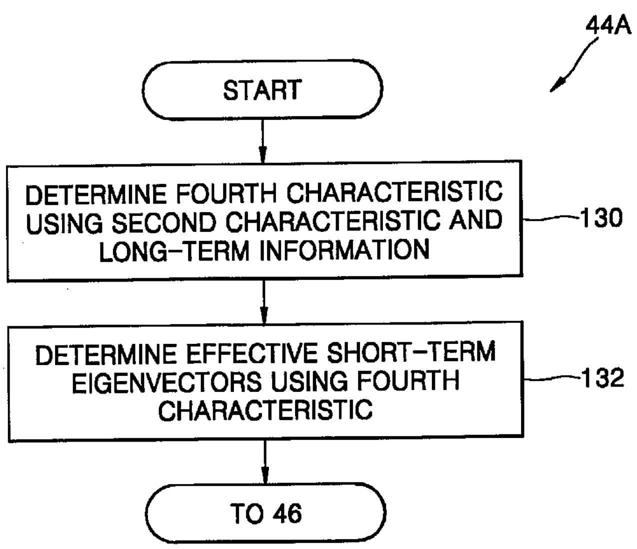

44A
START
DETERMINE FOURTH CHARACTERISTIC USING SECOND CHARACTERISTIC AND LONG-TERM INFORMATION
130
DETERMINE EFFECTIVE SHORT-TERM EIGENVECTORS USING FOURTH CHARACTERISTIC
132
TO 46

FIG. 9

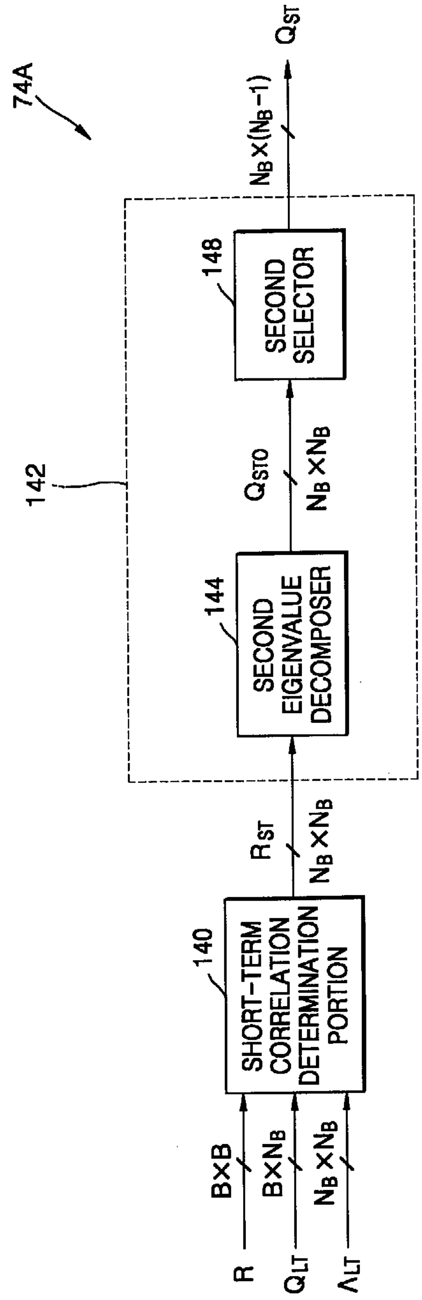

74A
142
R
Q_LT
Λ_LT
B×B
B×N_B
N_B×N_B
140
SHORT-TERM CORRELATION DETERMINATION PORTION
R_ST
N_B×N_B
144
SECOND EIGENVALUE DECOMPOSER
Q_STO
N_B×N_B
148
SECOND SELECTOR
N_B×(N_B-1)
Q_ST

FIG. 10

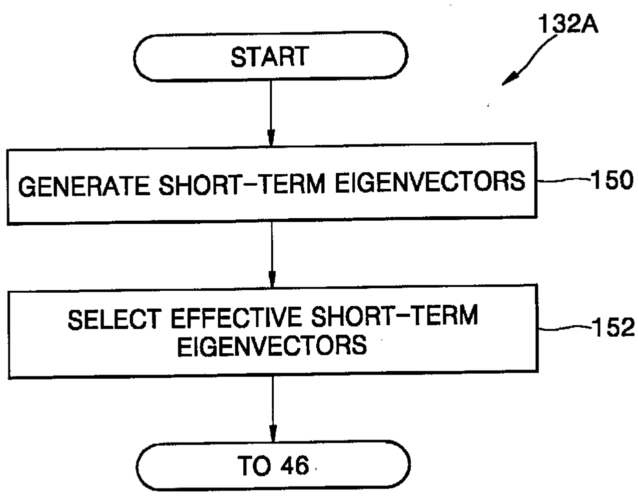

132A
START
GENERATE SHORT-TERM EIGENVECTORS
150
SELECT EFFECTIVE SHORT-TERM EIGENVECTORS
152
TO 46

FIG. 11

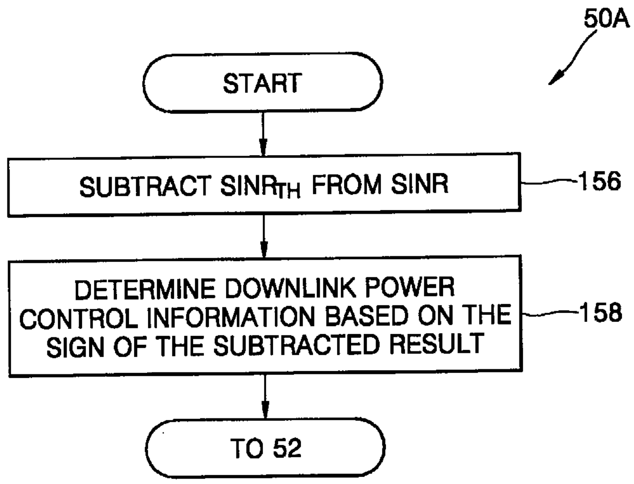

50A
START
SUBTRACT $SINR_{TH}$ FROM SINR
156
DETERMINE DOWNLINK POWER CONTROL INFORMATION BASED ON THE SIGN OF THE SUBTRACTED RESULT
158
TO 52

FIG. 12

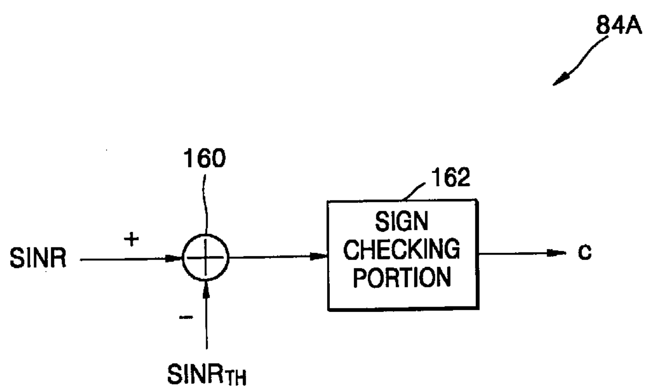


FIG. 13

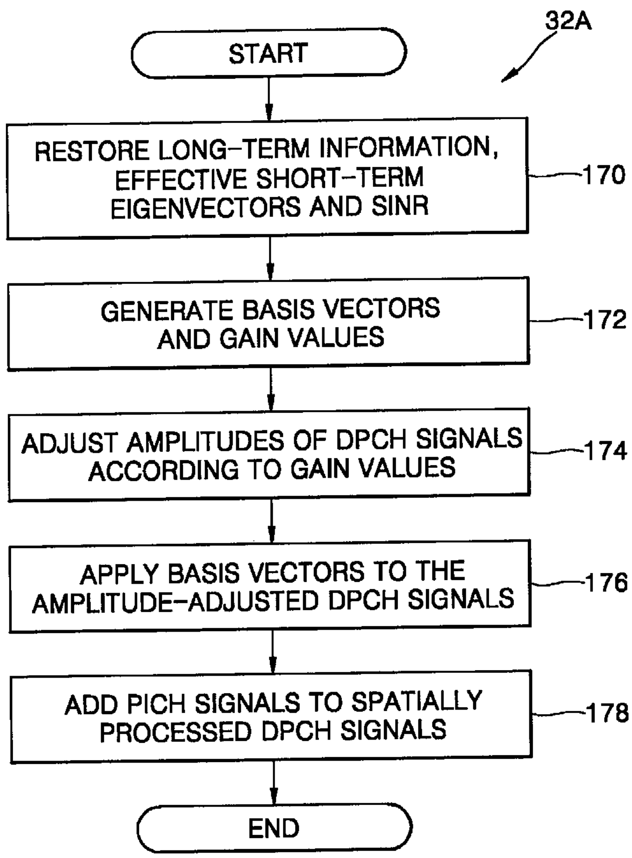
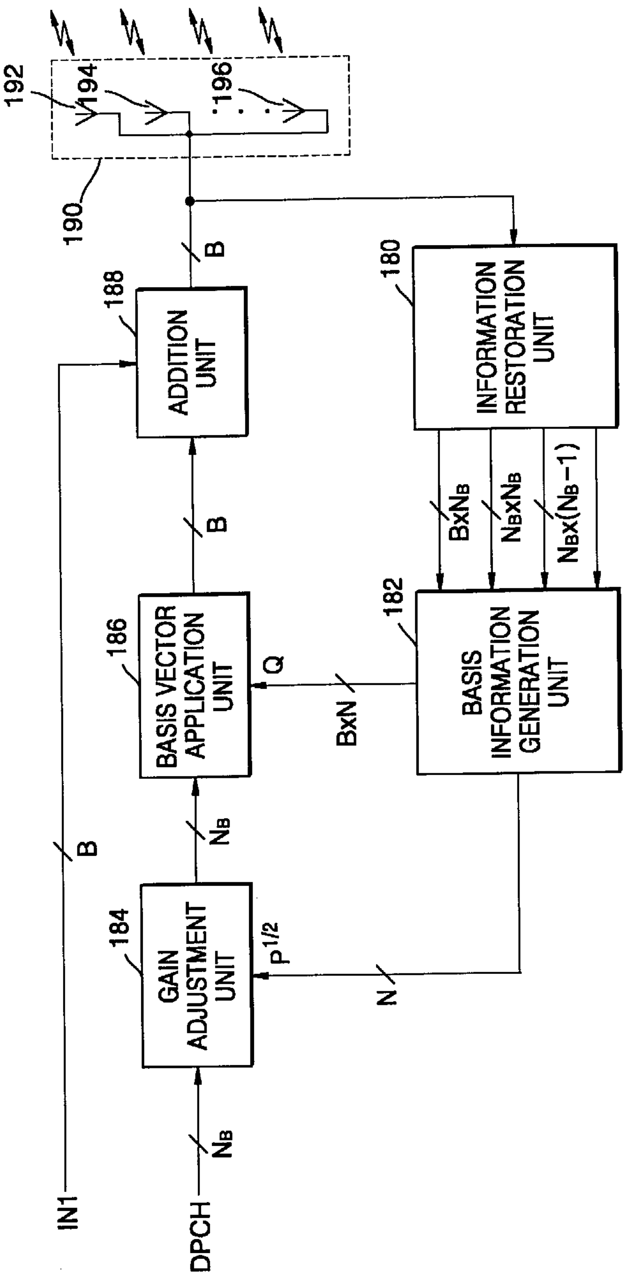

32A
START
RESTORE LONG-TERM INFORMATION, EFFECTIVE SHORT-TERM EIGENVECTORS AND SINR
170
GENERATE BASIS VECTORS AND GAIN VALUES
172
ADJUST AMPLITUDES OF DPCH SIGNALS ACCORDING TO GAIN VALUES
174
APPLY BASIS VECTORS TO THE AMPLITUDE-ADJUSTED DPCH SIGNALS
176
ADD PICH SIGNALS TO SPATIALLY PROCESSED DPCH SIGNALS
178
END

FIG. 14



IN1
DPCH
GAIN ADJUSTMENT UNIT
184
BASIS VECTOR APPLICATION UNIT
186
ADDITION UNIT
188
INFORMATION RESTORATION UNIT
180
BASIS INFORMATION GENERATION UNIT
182
190
192
194
196
B
N
BxN
Q
BxNB
NBxNB
NBx(NB−1)
P1/2

FIG. 15

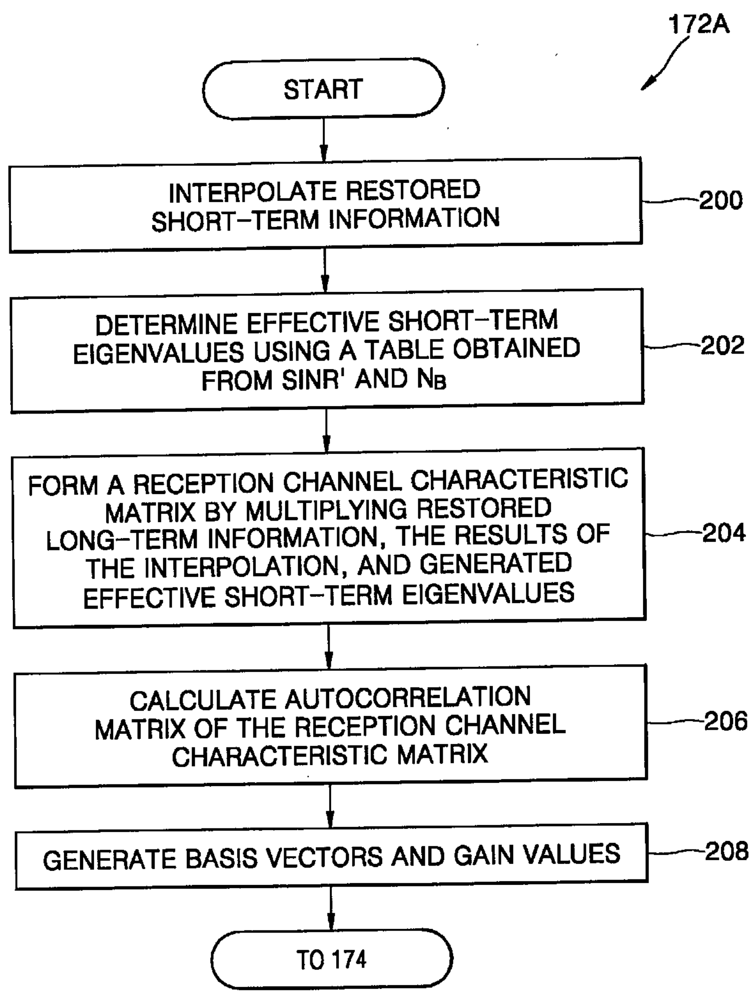

172A
START
INTERPOLATE RESTORED SHORT-TERM INFORMATION
200
DETERMINE EFFECTIVE SHORT-TERM EIGENVALUES USING A TABLE OBTAINED FROM SINR' AND NB
202
FORM A RECEPTION CHANNEL CHARACTERISTIC MATRIX BY MULTIPLYING RESTORED LONG-TERM INFORMATION, THE RESULTS OF THE INTERPOLATION, AND GENERATED EFFECTIVE SHORT-TERM EIGENVALUES
204
CALCULATE AUTOCORRELATION MATRIX OF THE RECEPTION CHANNEL CHARACTERISTIC MATRIX
206
GENERATE BASIS VECTORS AND GAIN VALUES
208
TO 174

FIG. 16

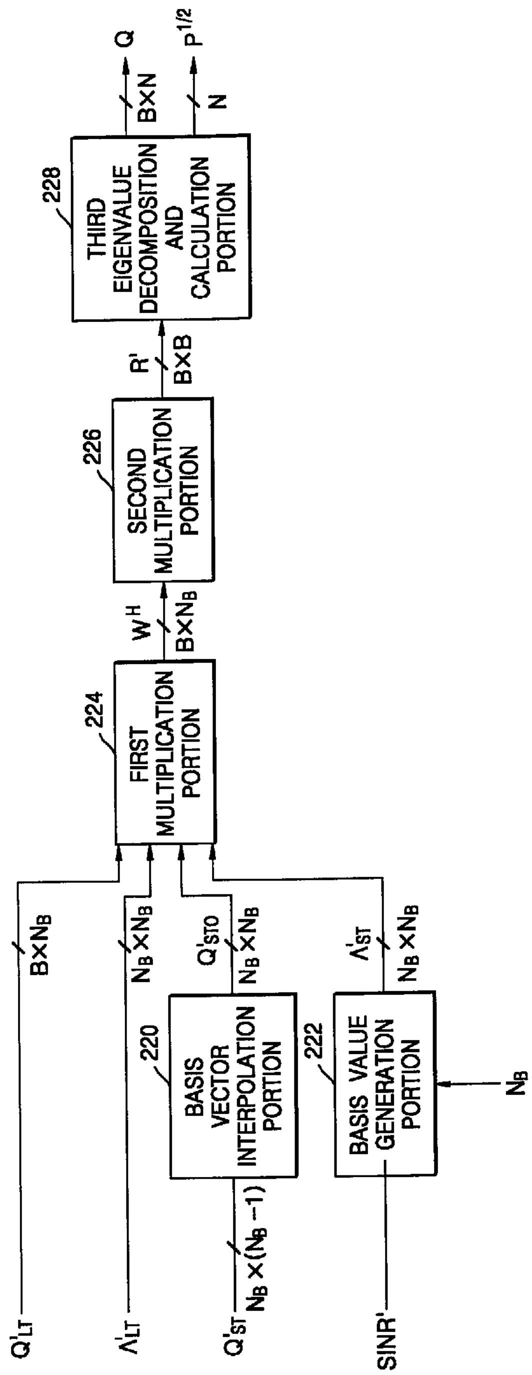
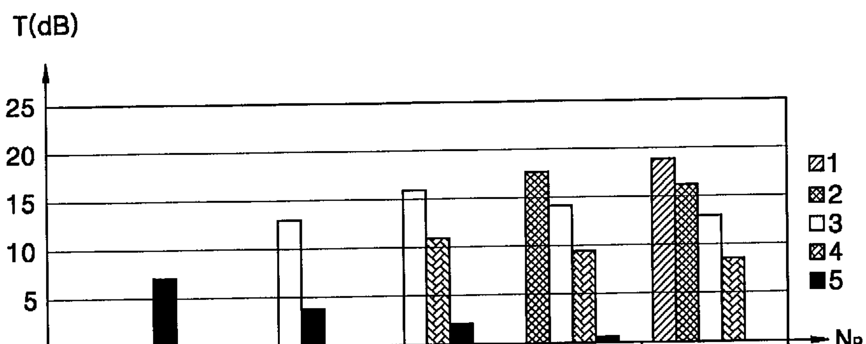

Q'LT
Λ'LT
Q'ST
SINR'
B×NB
NB×NB
NB×(NB−1)
220
BASIS VECTOR INTERPOLATION PORTION
Q'STO
NB×NB
222
BASIS VALUE GENERATION PORTION
NB
Λ'ST
NB×NB
224
FIRST MULTIPLICATION PORTION
WH
B×NB
226
SECOND MULTIPLICATION PORTION
R'
B×B
228
THIRD EIGENVALUE DECOMPOSITION AND CALCULATION PORTION
B×N
Q
N
P1/2

FIG. 17



	1×1 (N_B=1)	2×2 (N_B=2)	3×3 (N_B=3)	4×4 (N_B=4)	5×5 (N_B=5)
1	0	0	0	0	19.11340232
2	0	0	0	17.79630114	16.37261602
3	0	0	16.0156392	14.31234504	13.16017999
4	0	13.13857986	11.06878461	9.678054698	8.67127415
5	7.004298165	3.915575233	2.225682468	0.841327574	0

FIG. 18

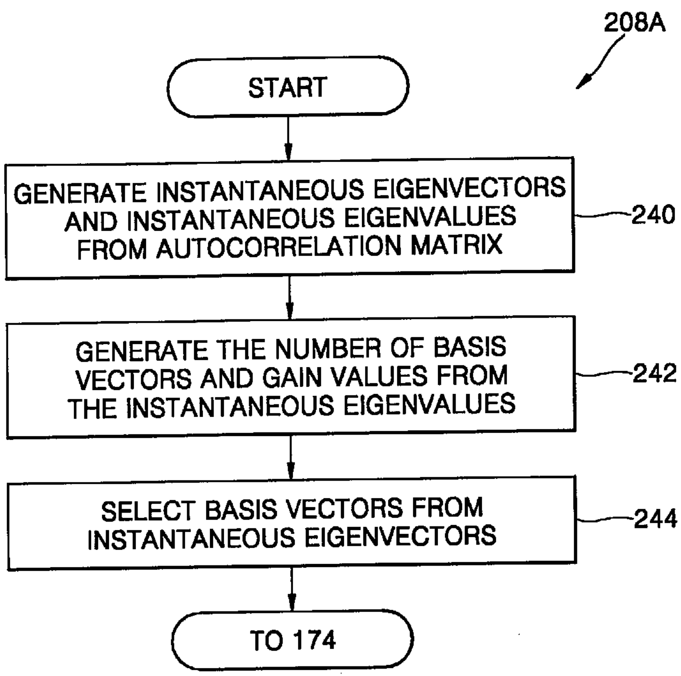

208A
START
GENERATE INSTANTANEOUS EIGENVECTORS AND INSTANTANEOUS EIGENVALUES FROM AUTOCORRELATION MATRIX
240
GENERATE THE NUMBER OF BASIS VECTORS AND GAIN VALUES FROM THE INSTANTANEOUS EIGENVALUES
242
SELECT BASIS VECTORS FROM INSTANTANEOUS EIGENVECTORS
244
TO 174

FIG. 19

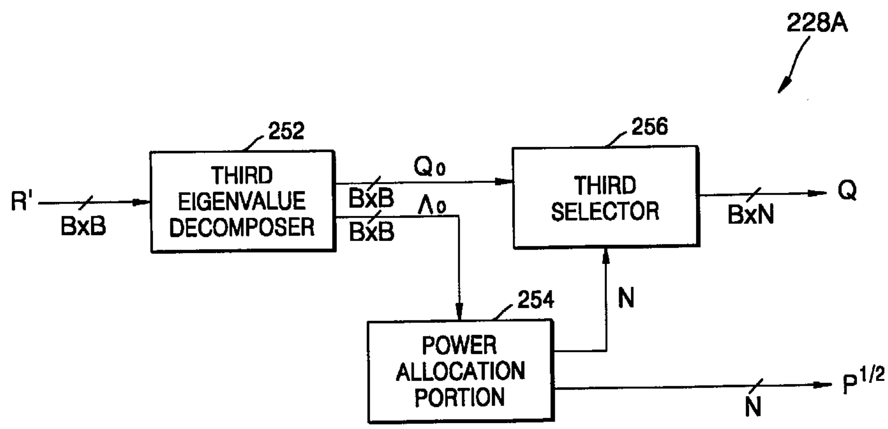

228A
252
THIRD EIGENVALUE DECOMPOSER
256
THIRD SELECTOR
254
POWER ALLOCATION PORTION
R'
BxB
Q0
BxB
Λ0
BxB
BxN
Q
N
N
P1/2

FIG. 20

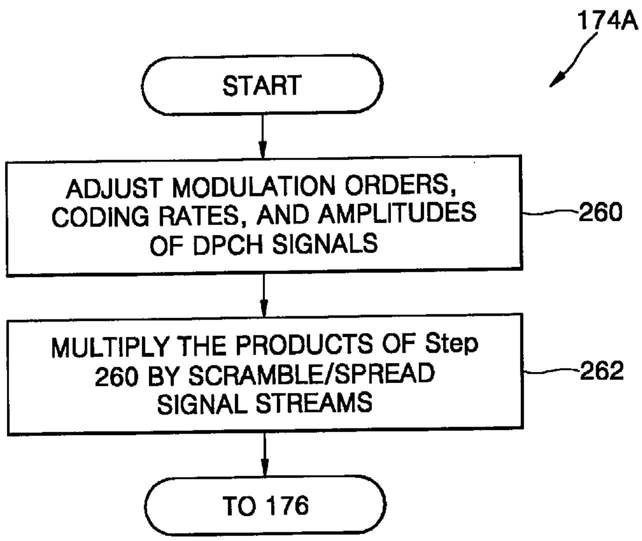

174A
START
ADJUST MODULATION ORDERS, CODING RATES, AND AMPLITUDES OF DPCH SIGNALS
260
MULTIPLY THE PRODUCTS OF Step 260 BY SCRAMBLE/SPREAD SIGNAL STREAMS
262
TO 176

FIG. 21

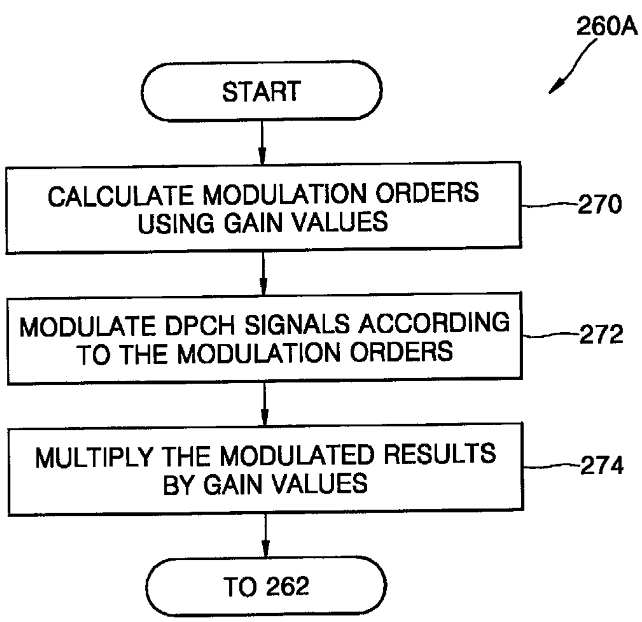

260A
START
CALCULATE MODULATION ORDERS USING GAIN VALUES
270
MODULATE DPCH SIGNALS ACCORDING TO THE MODULATION ORDERS
272
MULTIPLY THE MODULATED RESULTS BY GAIN VALUES
274
TO 262

FIG. 22

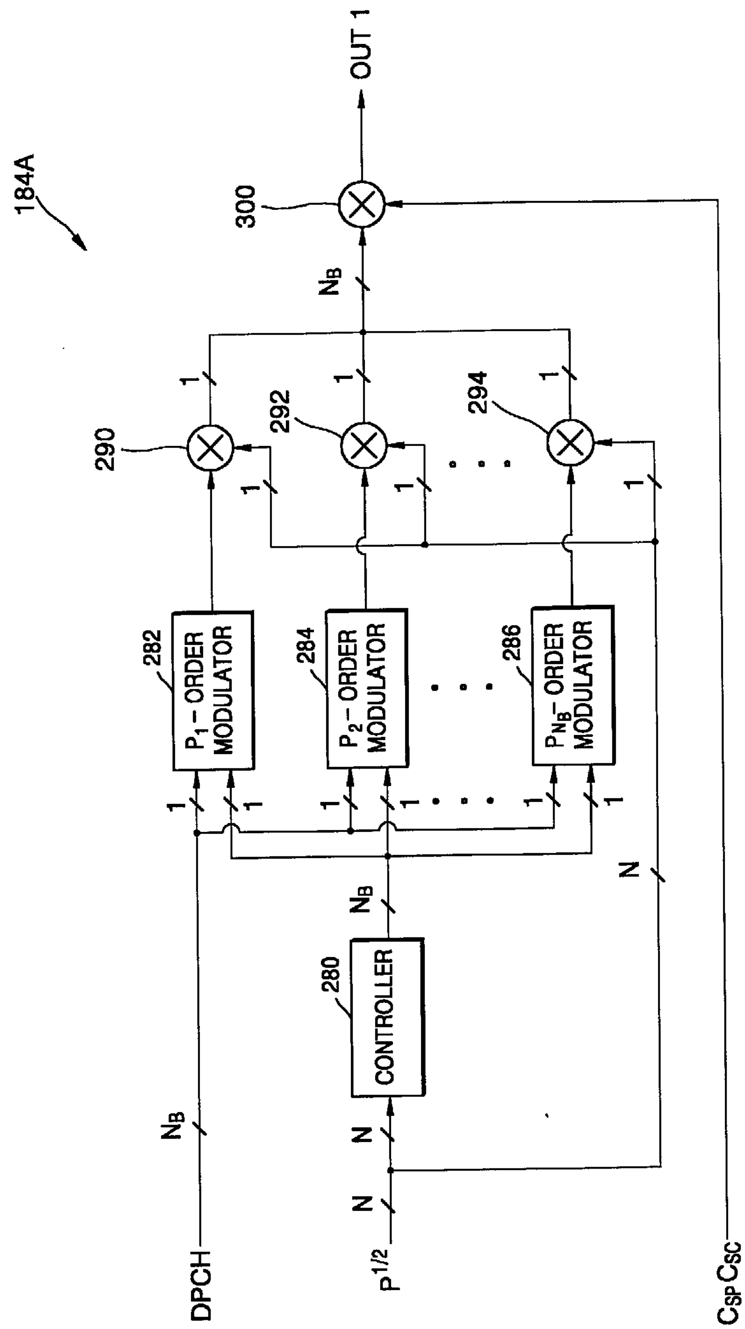

184A
OUT 1
300
N_B
290
292
294
1
P_1- ORDER MODULATOR
282
P_2- ORDER MODULATOR
284
P_{N_B}- ORDER MODULATOR
286
CONTROLLER
280
N
DPCH
$P^{1/2}$
$C_{SP}C_{SC}$

FIG. 23